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TECHNICAL REPORT

Household and similar electrical appliances – Method of measuring performance – Assessment of repeatability, reproducibility and uncertainty

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HOUSEHOLD AND SIMILAR ELECTRICAL APPLIANCES – METHOD OF MEASURING PERFORMANCE – ASSESSMENT OF REPEATABILITY, REPRODUCIBILITY AND UNCERTAINTY

FOREWORD

IEC 63250 has been prepared IEC technical committee 59: Performance of household and similar electrical appliances. It is a Technical Report.

The text of this Technical Report is based on the following documents

Draft	Report on voting
59/752/DTR	59/765/RVDTR

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this Technical Report is English.

Words **in bold** in the text are defined in Clause 3.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

INTRODUCTION

To encourage the efficient use of energy and other resources, national governments and regional authorities have issued regulations that mandate the provision of information to consumers regarding the energy and water consumption of household appliances and associated performance characteristics.

Therefore, methods for measuring performance characteristics must be of sufficient **accuracy** to provide confidence to governments, consumers and manufacturers.

The **accuracy** of a test method is expressed in terms of **bias** and **precision**. **Precision**, when evaluating test methods, is expressed in terms of two measurement concepts: **repeatability** (intra-laboratory variability) and **reproducibility** (inter-laboratory variability). Therefore, standard procedures are required for determining the **repeatability** and the **reproducibility** of test methods. The determination of levels of **repeatability** and **reproducibility** is frequently done by carrying out **round robin tests** (RRT). The **repeatability** of a test method must be sufficiently accurate for comparative testing. The **reproducibility** of a test method must be sufficiently accurate for the determination of values that are declared, and for checking these declared values. Other ways to assess the uncertainty are possible.

Uncertainty reporting is essential to ensure measured data are interpreted correctly. Especially when data of measurements are to be compared between laboratories or when normative requirements are set up, it is necessary to know the uncertainty with which data can be measured.

In conformity assessment using a binary decision rule, a property of an item is measured, and the item is accepted as conforming if the measured value of the property lies within a defined acceptance interval. A measured value outside the acceptance interval leads to rejection of the item as non-conforming.

The objective of this technical report is to give guidelines for household and similar electrical appliances within TC 59, but it can also be used for assessing other types of appliances outside the technical committee 59 and its subcommittees' environment.

It is intended to collate and summarise the information needed for assessing the **repeatability**, **reproducibility** and uncertainty of measurements of performance of household and similar electrical appliances present in previous IEC publications[1].

1 IEC TR 61923, IEC TR 62617 and IEC TR 62970

HOUSEHOLD AND SIMILAR ELECTRICAL APPLIANCES – METHOD OF MEASURING PERFORMANCE – ASSESSMENT OF REPEATABILITY, REPRODUCIBILITY AND UNCERTAINTY

1 Scope

This Technical Report deals with the determination of **repeatability** and **reproducibility** of test methods used for assessing the performance characteristics of household and similar electrical appliances. It also provides guidance for carrying out **round robin tests** (RRT).

It also specifies the uncertainty reporting of measurements of household and similar electrical appliances.

It describes methods to estimate the uncertainty of a measured result and to predict the range of measured values when the same appliance is measured in another laboratory applying the same measurement method.

It does not cover the development of measurement methods. It also does not deal with:

– the production variability of the appliance;

– how closely the measurement method reflects the normal use of appliances in households.

NOTE 1 Although this technical report does not cover the development of test methods, it can be taken into consideration for this purpose.

NOTE 2 For the purpose of this technical report production variability includes the variation of the individual appliances of the same type and model manufactured on the same production line.

NOTE 3 For noise standardisation, some deviating definitions are used (see. IEC 60704-3:2019).

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 5725-2:2019, *Accuracy (trueness and precision) of measurement methods and results – Part 2: Basic method for the determination of repeatability and reproducibility of a standard measurement method*

ISO 80000-1:2009, *Quantities and units – Part 1: General*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1
accuracy
closeness of agreement between a test result or measurement result and the true value

Note 1 to entry: In practice, the accepted reference value is substituted for the true value.

Note 2 to entry: The term "**accuracy**", when applied to a set of test or measurement results, involves a combination of random components and a common systematic error or **bias** component.

Note 3 to entry: **Accuracy** refers to a combination of trueness and **precision**.

[SOURCE: ISO 3534-2:2006, 3.3.1, modified – Cross-references have been deleted]

3.2
precision
closeness of agreement between independent test/measurement results obtained under stipulated conditions

Note 1 to entry: **Precision** depends only on the distribution of random errors and does not relate to the true value or the specified value.

Note 2 to entry: The measure of **precision** is usually expressed in terms of imprecision and computed as a standard deviation of the test results or measurement. Less **precision** is reflected by a larger standard deviation.

Note 3 to entry: Quantitative measures of **precision** depend critically on the stipulated conditions. **Repeatability conditions** and **reproducibility conditions** are particular sets of extreme stipulated conditions.

[SOURCE: ISO 3534-2:2006, 3.3.4, modified – Cross-references have been deleted]

3.3
repeatability
precision under **repeatability conditions**.

Note 1 to entry: **Repeatability** can be expressed quantitatively in terms of the dispersion characteristics of the results.

[SOURCE: ISO 3534-2:2006, 3.3.5, modified – Cross-references have been deleted]

3.4
repeatability conditions
observation conditions where independent test/measurement results are obtained with the same method on identical test/measurement items in the same test or measuring facility by the same operator using the same equipment within short intervals of time

Note 1 to entry: **Repeatability** conditions include:

- the same measurement procedure or test procedure;
- the same operator;
- the same measuring or test equipment used under
- the same conditions;
- the same location;
- repetition over a short period of time.

[SOURCE: ISO 3534-2:2006, 3.3.6, modified – Cross-references have been deleted]

3.5
repeatability standard deviation
standard deviation of test results or measurement results obtained under **repeatability conditions**

Note 1 to entry: It is a measure of the dispersion of the distribution of test results or measurement results under **repeatability conditions**.

Note 2 to entry: Similarly, "repeatability variance" and "repeatability coefficient of variation" can be defined and used as measures of the dispersion of test or measurement results under **repeatability conditions**.

[SOURCE: ISO 3534-2:2006, 3.3.7, modified – Cross-references have been deleted]

3.6
reproducibility
precision under **reproducibility conditions**

Note 1 to entry: **Reproducibility** can be expressed quantitatively in terms of the dispersion characteristics of the results.

Note 2 to entry: Results are usually understood to be corrected results

[SOURCE: ISO 3534-2:2006, 3.3.10, modified – Cross-references have been deleted]

3.7
reproducibility conditions
observation conditions where independent test/measurement results are obtained with the same method on identical test/measurement items in different test or measurement facilities with different operators using different equipment

[SOURCE: ISO 3534-2:2006, 3.3.11, modified – Cross-references have been deleted]

3.8
reproducibility standard deviation:
standard deviation of test results or measurement results obtained under **reproducibility conditions**

Note 1 to entry: It is a measure of the dispersion of the distribution of test or measurement results under **reproducibility conditions**.

Note 2 to entry: Similarly, "reproducibility variance" and "reproducibility coefficient of variation" can be defined and used as measures of the dispersion of test or measurement results under **reproducibility conditions**.

[SOURCE: ISO 3534-2:2006, 3.3.12 modified – Cross-references have been deleted]

3.9
outlier
member of a small subset of observations that appears to be inconsistent with the remainder of a given sample

Note 1 to entry: The classification of an observation or a subset of observations as **outlier(s)** is relative to the chosen model for the population from which the data set originates. This or these observations are not to be considered as genuine members of the main population.

Note 2 to entry: An **outlier** may originate from a different underlying population, or be the result of incorrect recording or gross measurement error.

Note 3 to entry: The subset may contain one or more observations.

[SOURCE: ISO 16269-4:2010, 2.2 modified – Cross-references have been deleted]

3.10
statistical uncertainty
repeatability standard deviation obtained in one laboratory under **repeatability conditions**

3.11
expanded uncertainty
quantity defining an interval about the result of a measurement that may be expected to encompass a large fraction of the distribution of values that could reasonably be attributed to the measurand

Note 1 to entry: The fraction may be viewed as the coverage probability or level of confidence of the interval.

Note 2 to entry: To associate a specific level of confidence with the interval defined by the expanded uncertainty requires explicit or implicit assumptions regarding the probability distribution characterized by the measurement result and its combined standard uncertainty. The level of confidence that may be attributed to this interval can be known only to the extent to which such assumptions may be justified.

Note 3 to entry: **Expanded uncertainty** is termed *overall uncertainty* in paragraph 5 of Recommendation INC-1 (1980)

[SOURCE: ISO/IEC Guide 98-3:2008, 2.3.5]

3.12
bias
difference between the expectation of a test result or measurement result and a true value

[SOURCE: ISO 3534-2:2006, 3.3.2, modified – Cross-references and Notes have been deleted]

3.13
round robin testing
RRT
ringtest
process in which one or more items are tested according to a specific protocol by a number of different laboratories.

4 Determination of standard deviations

4.1 General

Repeatability and **reproducibility standard deviations** serve as parameters for assessing:

– the suitability of a measurement method;
– the **accuracy** of a measurement result;
– conformance of measured values to acceptance interval.

Rounding is only applied to reported values in Clause 7. If numbers are rounded, they are rounded to the nearest number in accordance with ISO 80000-1:2009, Annex B, Rule B. If the rounding takes place to the right of the comma, the omitted places are not filled with zeros.

4.2 Repeatability standard deviation

The **repeatability standard deviation** $s_{L,i}$ of a measurement method within laboratory i is calculated from Equation (1):

$$s_{L,i} = \sqrt{\frac{1}{n_i - 1} \sum_{k=1}^{n_i} \left(x_{ki} - \overline{x}_i\right)^2} \quad (1)$$

where

n_i is the number of measurement results;

x_{ki} is the particular measurement result;

$\overline{x}_i$ is the arithmetic mean value of n_i measurement results x_k of laboratory i.

The average **repeatability standard deviation** s_r of a measurement method within p laboratories is calculated from Equation (2):

$$s_r = \sqrt{\frac{1}{p} \sum_{i=1}^{p} s_{L,i}^2} \quad (2)$$

where

$s_{L,i}$ is the **repeatability standard deviation** within laboratory i;

p is the number of laboratories participating in the inter-laboratory test.

4.3 Reproducibility standard deviation

The **reproducibility standard deviation** s_R of a measurement method is calculated from Equations (3), (4), and (5):

$$x_m = \frac{1}{p} \sum_{i=1}^{p} \overline{x}_i \qquad (3)$$

$$n = \frac{1}{p} \sum_{i=1}^{p} n_i \qquad (4)$$

$$s_R = \sqrt{\frac{1}{p-1} \sum_{i=1}^{p} \left(\overline{x}_i - x_m\right)^2 + \frac{n-1}{n} s_r{}^2} \qquad (5)$$

where x_m is the arithmetic mean value of the arithmetic mean values $\overline{x}_i$ of the participating laboratories and n is the number of measurements in all laboratories.

NOTE s_R is expected to be greater than s_r .

5 Assessment of repeatability, reproducibility, and uncertainty of a measurement method

5.1 Purpose

The purpose of assessing the **repeatability** and the **reproducibility** is to determine whether a method of measurement is suitable for comparative testing only or for the determination and verification of values independent of the laboratory performing the measurement.

A low **repeatability standard deviation** is necessary to determine whether a method of measurement is suitable for comparative testing. A low **reproducibility standard deviation** is necessary to determine whether this method of measurement is suitable for determination and verification of values independent of the laboratory performing the measurement. A more general expression of the **reproducibility** of a measurement is the uncertainty of the measurement method. This concept can be either based on the adequate mathematical description and analysis of the input quantities and their uncertainties (5.4.2 a) or by measurement of the **reproducibility**, for example by performing and analysing a **round robin test** (5.4.2 b).

In conformity assessment that uses a binary decision rule, a property of an item is measured, and the item is accepted as conforming if the measured value of the property lies within a defined acceptance interval. A measured value outside the acceptance interval leads to rejection of the item as non-conforming. The acceptance interval is either an externally imposed interval of conforming values or a mutually agreed interval of permissible values.

5.2 Requirements

The following requirements are taken into account when assessing the **reproducibility** and/or **repeatability** of a measurement method:

a) **repeatability** and **reproducibility** of a measurement method are assessed by an interlaboratory test;

NOTE Data obtained in interlaboratory studies can indicate that further effort is needed to improve the measurement method.

b) the necessary number of measurements and laboratories participating in an interlaboratory test depends on the type of appliance and are established by the responsible body. With respect to a statistical evaluation of the measurement results, at least five measurement results from each of at least five laboratories, excluding any **outlier**, should be available. The number of measurements is the same for each laboratory;

c) the test procedures are specified completely and accurately, including the rounding of values from measurement results, the **accuracy** of the measuring instruments and the environmental conditions, as appropriate;

d) wherever possible, precise values of intermediate results (without rounding) should be recorded and used in subsequent calculations to ensure that the final result is as accurate as possible;

e) the test laboratories shall adhere to the measurement procedure specified in the standard or in the test programme;

f) only appliances with low variability shall be used;

g) the reference appliance, if any, shall have the lowest variability.

5.3 Expression of repeatability and reproducibility

Reproducibility standard deviation can be a value of absolute or relative nature. Depending on the nature of the error, either one or the other shall be preferred. Absolute values of the **reproducibility standard deviation** shall be preferred when the measurement error is not likely to be influenced by the absolute value of the measurand. Relative values are preferred when the error will grow or diminish with the absolute magnitude of the measurand.

5.4 The approach to uncertainty

5.4.1 The importance of the uncertainty

When a measurement has been performed giving a value as a result for some quantity (i.e. the measurand), how accurate is the measurand? In other words:

– if the measurement is repeated, will the same value be achieved as the initial result?

– if another group or another laboratory performs the measurement, how close are the results expected to be?

By means of an uncertainty amount, an uncertainty interval $y \pm U$ may be calculated, where y is the measurement result and U the **expanded uncertainty** that is determined to give the interval a high probability (often 95 %) to cover the true value, y, of the measurand. U is said to be the uncertainty associated with the result y.

The uncertainty interval of a measurement is therefore a basis for qualifying the measurement. The narrower the confidence interval desired, i.e. the smaller the value of the uncertainty U, the more care is needed for the measurement method, the measuring equipment, the training of the operators, and the number of repetitions of the same experiment.

5.4.2 Methods to estimate uncertainty

There are in principle two ways to estimate uncertainty: a bottom-up method and a top-down method. The two methods should often be used in parallel to achieve a reliable uncertainty amount.

a) The bottom-up method (Refer to ISO/IEC GUIDE 98-3:2008 and Annex A for an example)

In this method, the measurement result y is expressed as a function of input quantities. This function is often the formula used for the calculation of the result.

In the case of home laundry appliances, y can represent one of the final measurement results such as water consumption, energy consumption, washing performance, spin speed, spin drying performance, programme duration or rinsing efficiency. The input quantities can be temperature, masses, times, power, etc.

The magnitude of all the uncertainty contributions of each input quantity is estimated.

By combining the uncertainties of the input quantities according to the law of propagation of uncertainty (see Clause 2 of ISO/IEC GUIDE 98-3:2008), the uncertainty of the result y can be calculated.

With this calculation, it can be seen how a specific uncertainty contribution from an input quantity influences the combined uncertainty of the final result, and, therefore, how a reduction in an uncertainty contribution from an input quantity will influence the combined uncertainty of the final result.

Uncertainties can usually be reduced at some cost by making more measurements, using other methods or other equipment. This means that different approaches can be followed to reduce the uncertainty of the final result in the most cost-effective way.

Bottom-up calculations of uncertainty of results can be checked for consistency through inter-laboratory comparisons. If, for example, a reference test material is used in the measurement, its properties should be consistent between laboratories.

NOTE This turned out to not be the case for the carpet used as reference for the dust pick up measurement of vacuum cleaners. Such mistakes or errors might be found only by measurement in different laboratories, e.g. through a **round robin test** or other top-down methods

b) The top-down method (Annex B and Annex C)

In this method, the **reproducibility standard deviation** is estimated from testing of the same machine (or the same model) in different laboratories using the same measurement method. This testing is in general named '**ringtest**' or '**round robin test**'. The **reproducibility standard deviation** of the measurement results can then be seen as the inherent uncertainty of the measuring method because it can be influenced by remaining differences in the ambient conditions, test personnel, and whatever else may be different between different measurements in different laboratories. In principle, it is only valid for the machine investigated in each ringtest, but results can be also true for similar types of machines.

Therefore, the two methods 'bottom up' and 'top down' may be used in parallel to achieve a reliable uncertainty quantification. However, both methods depend on the validity of the model (for the bottom-up method) or the data (for the top-down method) used.

5.4.3 Expanded uncertainty calculation

The uncertainty of a measured result has two sources:

– the **statistical uncertainty** of what is measured, as expressed in the **repeatability standard deviation,** showing the **accuracy** of the measurement in the laboratory having done the measurement;

– the uncertainty of the measuring method itself. This is expressed as **expanded uncertainty** where it is common to set the borders at a 95 % confidence interval, which is the minimum and maximum value range within which the average measured result can be found when the measurement is re-done at any other laboratory.

To be meaningful, the uncertainty statement must have an associated confidence level: i.e. it is necessary to state the probability that the true value lies within the range given. The reasons for choosing a 95 % confidence level in this document are as follows:

– it is established practice throughout much of Europe, North America, and Asia (see ISO/IEC GUIDE 98-3:2008);

– ISO/IEC GUIDE 98-3:2008 assumes that the combined uncertainty has a distribution that is a close approximation to a normal distribution. A 95 % confidence level approximates to a range of 2 times the standard deviation. It is a widely held view that, for most measurement systems, the approximation to a normal distribution for the distribution of the combined uncertainty is reliable out to 2 standard deviations, but beyond that the approximation is less reliable.

If a normal distribution can be assumed, the 95 % confidence interval is given by multiplying the **reproducibility standard deviation** by a factor of 2 to calculate the **expanded uncertainty** of a measurand.

Like **reproducibility standard deviation** (5.3), the **expanded uncertainty** can be a value of absolute or relative nature. Depending on the nature of the error, either one or the other is preferred. It is the responsibility of the responsible standardisation committee to conclude in which way the **expanded uncertainty** is expressed. If expressed in absolute values, the **expanded uncertainty** is given with the term '(abs)', otherwise in '%'.

Examples of the expression of values are given in Annex D.

6 Scrutiny of results for consistency and outliers

6.1 Purpose

Outliers related to measurement results as well as to test laboratories are scarce but cannot always be avoided. They are taken into consideration, but they should not lead to a distortion of the results of a test which has been carried out to assess the **repeatability** and **reproducibility** of a measurement method. An example is shown in Annex C with Table C.1 and Table C.2

A statistical procedure by which suspect measurement results or laboratories are judged is not specified. The final decision about the treatment of **outliers** (e.g. repetition of a test or ignoring results) is taken by the responsible body with justification.

NOTE The scrutiny of measurement results for consistency and **outliers** is based on 8.3 in ISO 5725-2:2019; attention is drawn to 8.3.3.2 in ISO 5725-2:2019 concerning the application of Cochran's and Grubb's tests.

6.2 Graphical consistency technique (Mandel's *h* and *k* statistics)

6.2.1 Inter-laboratory consistency statistic *h*

The inter-laboratory consistency statistic h_i for laboratory i is calculated from Equation (6):

$$h_i = \frac{\overline{x}_i - x_m}{\sqrt{\frac{1}{p-1}\sum_{i=1}^{p}\left(\overline{x}_i - x_m\right)^2}} \qquad (6)$$

6.2.2 Intra-laboratory consistency statistic *k*

The intra-laboratory consistency statistic k_i for laboratory i is calculated by Equation (7):

$$k_i = \frac{s_{L,i}}{s_r} \qquad (7)$$

6.2.3 Evaluation

The calculated values are plotted as appropriate (refer to the examples of Table C.3 and Figure C.1 and Figure C.2). Lines are drawn on the plots corresponding to the indicators given in Tables 7 and 8 in ISO 5725-2:2019. These indicator lines serve as guidance when examining patterns in the data.

– Various patterns can appear in the h plots. All laboratories can have both positive and negative values. Neither of these patterns is unusual nor requires investigation. But if all the h values for one laboratory are of one sign, and the h values for the other laboratories are all of the other sign, then the reason should be sought.

– If one laboratory stands out on the k plot presenting many large values, then the reason should be sought: this indicates that it has a poorer **repeatability** than the other laboratories. A laboratory could give rise to consistently small k values because of such factors as excessive rounding of its data or measurement scale with inadequate resolution.

If the h and k plots indicate that specific laboratories exhibit patterns of results that are markedly different from the others, this laboratory should be contacted to ascertain the cause of the different behaviour. The responsible body could:

a) accept the laboratory's data as possible interim result;

b) ask the laboratory to redo the measurement (if feasible);

c) delete the laboratory's data from the study.

6.3 Numerical outlier technique

6.3.1 Cochran's C test

Cochran's criterion applies strictly only when all the standard deviations are derived from the same number (n) of measurement results obtained under **repeatability conditions**. It tests only the highest value in a set of standard deviations and is therefore a one-sided **outlier** test.

Small values of standard deviation can be very strongly influenced by the degree of rounding of the original data and are, for that reason, not very representative of the laboratory. If the standard deviations for a particular laboratory are at all or at most levels lower than those for other laboratories, this can indicate that the laboratory works with a lower **repeatability standard deviation** than the other laboratories. This can be caused either by better technique and equipment, or by a modified or incorrect application of the measurement method.

The Cochran's test statistic C_i for laboratory i is calculated with Equation (8):

$$C_i = \frac{s_{L\max}^2}{\sum_{i=1}^{p} s_{L,i}^2} \tag{8}$$

where $s_{L\max}$ is the highest standard deviation in the set.

If the highest standard deviation is classed as an **outlier**, then the value should be omitted, and Cochran's test repeated on the remaining values.

6.3.2 Grubbs' test

In the following formula, only one outlying observation is considered. The Grubbs' statistic G_1 is calculated with Equation (9) and G_2 with Equation (10):

$$G_1 = \frac{\overline{x}_{\max} - x_m}{s_r} \tag{9}$$

$$G_2 = \frac{x_m - \overline{x}_{\min}}{s_r} \tag{10}$$

where

G_1 is the significance of the largest observation of an interlaboratory test;

G_2 is the significance of the smallest observation of an interlaboratory test.

NOTE Equation (8) and Equation (9) can also be applied to determine the significance of observations of a within-laboratory test by replacing $\overline{x}_{\max}$ and $\overline{x}_{\min}$ by $x_{k\max}$ and $x_{k\min}$, x_m by $\overline{x}_i$ and s_r by $s_{L,i}$.

6.3.3 Evaluation

Critical values are given in ISO 5725-2:2019, those for Cochran's C test in Table 5, and those for Grubbs' test in Table 6.

If the test statistic C or G (see Equation (7), Equation (8) and Equation (9)) is:

a) less than or equal to its critical value referred to the 5 % significance level, the item tested is accepted as correct;

b) greater than its critical value referred to the 5 % significance level and less than or equal to its critical value referred to the 1 % significance level, the item tested is called a straggler;

NOTE The critical values referred to the 1 % significance level are greater than the critical values referred to the 5 % significance level.

c) greater than its critical value referred to the 1 % significance level, the item tested is called a statistical **outlier**.

A visualisation is shown in Figure 1 and a numerical example is given in Clause C.3.2 and in Table C.4 and Table C.5.

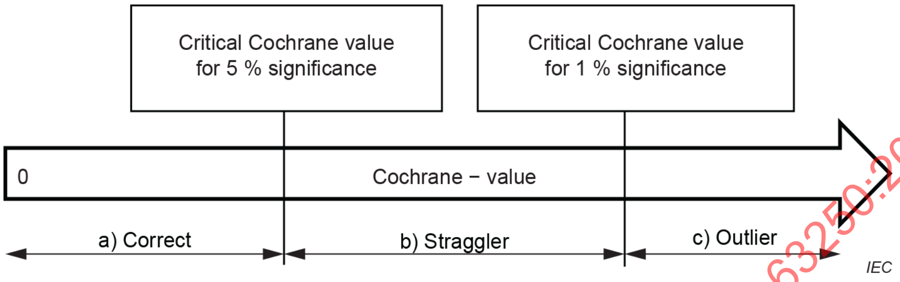

Figure 1 – Visualisation of straggler and outlier of Cochrane value

7 Data to be reported for assessing the repeatability, reproducibility and uncertainty of a test method

When reporting test results, all information is given to allow a full judgement of the measurement method:

a) identification of appliances used for the test;

b) the method of measurement;

c) identification of the laboratories which carried out the tests, including test personnel;

d) individual measurement results and average measured value;

e) **repeatability standard deviation** and **reproducibility standard deviation** according to 4.2 and 4.3;

f) percentage of acceptance interval for **repeatability** and **reproducibility** according to 5.1 (if appropriate);

g) insufficient consistency, **outliers** and stragglers determined according to Clause 6 and whether laboratories or **outliers** have been omitted;

h) relative or absolute **expanded uncertainty** according to 5.4.

Annex A
(informative)

Example of bottom-up analysis

A.1 General

This example describes part of an uncertainty analysis for measuring temperatures in a laboratory dedicated to measuring domestic refrigerators according to IEC 62552-1:2015, IEC 62552-2:2015, and IEC 62552-3:2015. This document requires a measurement uncertainty of 0,5 K (at a coverage factor of k = 2). A typical test included in this document is to measure the energy consumption. The temperature uncertainty propagates into the measured energy consumption because its value depends on the ambient temperature and the inside compartment temperatures. For determining the uncertainty of a compartment temperature, it is not enough to know the temperature measurement uncertainty, but also other factors, such as the exact location of the sensor in a compartment, in particular if measurement packages are applied. This kind of error propagation is important for final statements concerning uncertainty, but is not discussed in this example which is limited to the temperature measurement itself.

A.2 Temperature measurement system

A.2.1 General

The temperature measurement system under analysis consists of Data AcQuisition (DAQ) systems (using T-type thermocouples), which are placed outside the climate rooms. Inside the climate rooms, there are test positions to accommodate domestic refrigerator / freezers. At each test position, temperature measurement channels are available on connector panels. These connector panels are connected to the DAQ systems by means of thermocouple compensation cabling.

The uncertainty of the temperature measurement system is estimated using the following procedures:

1) Calibration of the individual thermocouples
2) Calibration of the DAQ systems

A.2.2 Calibration of thermocouples

The thermocouples to be calibrated are connected to a reference DAQ system (DAQr). Subsequently, the thermocouples are inserted in a thermostatic bath and calibrated at 3 different temperatures: −23 °C, 0 °C and +43 °C, which comprise the complete temperature measurement regime of a domestic appliance. A Pt100 sensor in combination with an accurate reading instrument is used to determine the reference temperature of the bath. The calibration of the thermocouples is performed in an acclimatized room with a temperature of 23 °C ± 3 K.

A.2.3 Calibration of the DAQ system

The DAQ systems are calibrated using a thermocouple simulator connected to the connector panel inside the climate room while being operated at 25 °C. The simulator (SIM) produces a voltage corresponding to the desired calibration temperature of a T-type thermocouple and uses a Pt100 sensor as a cold junction reference. By means of a thermocouple multiplier (made out of the same materials as the 'normal' thermocouples used during the test), the voltage produced by the simulator is fed to 20 channels simultaneously. From the connector panels, the voltage is fed to the DAQ systems using thermocouple compensation cable.

A.3 Uncertainty temperature measurement

Within this clause, the **expanded uncertainty** (U) is determined applying a coverage factor of k = 2 (coverage probability of approximately 95 %) on the standard uncertainty (u). For further details of the calculation methodology applied, reference is made to ISO/IEC GUIDE 98-3:2008.

The temperature reading during measurement is presented by the following overall model. Note that the deviations listed here apply specifically to the measurement system being analysed.

$$T_{\mathrm{Meas}} = t(s) + \delta_{\mathrm{A\_SIM}} + \delta_{\mathrm{D\_SIM}} + \delta_{\mathrm{R\_cj}} + \delta_{\mathrm{D\_cj}} + \delta_{\mathrm{multi}} + \delta_{\mathrm{therm}} + \delta_{\mathrm{D\_DAQ}} + \delta_{\mathrm{A\_DAQ}} + \delta_{\Delta T} \quad \text{(A.1)}$$

The symbols used in Equation (A.1) are described in Table A.1.

Table A.1 – Description of uncertainty parameters

T_{meas}	Temperature reading of a thermocouple connected to a RTF	[°C]
$t(s)$	Temperature simulated by the TC simulator	[°C]
$\delta_{\mathrm{A\_SIM}}$	Temperature deviation for variation in ambient temperature of the TC simulator	[K]
$\delta_{\mathrm{D\_SIM}}$	Temperature deviation for drift of TC simulator	[K]
$\delta_{\mathrm{R\_cj}}$	Temperature reading of the cold junction sensor of the simulator	[K]
$\delta_{\mathrm{D\_cj}}$	Temperature deviation for drift of the cold junction sensor	[K]
δ_{multi}	Temperature deviation for the multiplier applied	[K]
δ_{therm}	Temperature deviation for thermocouple wiring applied	[K]
$\delta_{\mathrm{D\_DAQ}}$	Temperature deviation for drift of the DAQ system used	[K]
$\delta_{\mathrm{A\_DAQ}}$	Temperature deviation for variation in ambient of the DAQ system used	[K]
$\delta_{\Delta \mathrm{T}}$	Temperature correction for increased temperature difference over the thermocouple and compensation cabling between the connection block and the data acquisition system (i.e. climate room at a temperature different outside the range of 16 °C to 32 °C)	[K]

In the full analysis of this system, the uncertainty budget was estimated for three different temperatures (−23 °C, 0 °C and 43 °C), and for two different climate room temperatures ranges (a: within 16 °C to 32 °C, as these are relevant for energy testing in the referenced IEC standard, and b: outside the range of 16 °C and 32 °C). Both actual measured temperature level and the room temperature affect the uncertainty. As an example, the table of measuring −23 °C within a room operating between 16 °C and 32 °C is included (see Table A.2).

Table A.2 – Measuring a temperature of −23 °C at a climate room temperature between 16 °C to 32 °C

Quantity *X(i)*	Estimate *(xi)*	Standard uncertainty *u(xi)*	Probability distribution	Sensitivity coefficient *ci*	Uncertainty contribution *u(y)*
t(s)	−23,0 °C	0,025 K	Normal	1	0,025 K
δ_{A_SIM}	0,0 °C	0,0 K	Rectangular	1	0,0 K
δ_{D_SIM}	0,0 °C	0,029 K	Rectangular	1	0,029 K
δ_{R_cj}	0,0 °C	0,01 K	Rectangular	1	0,01 K
δ_{D_cj}	0,0 °C	0,029 K	Rectangular	1	0,029 K
δ_{multi}	0,0 °C	0,0 K	Rectangular	1	0,0 K
δ_{therm}	0,0 °C	0,139 K	Normal	1	0,139 K
δ_{D_DAQ}	0,0 °C	0,167 K	Rectangular	1	0,167 K
δ_{A_DAQ}	0,0 °C	0,0 K (0,05 K)[a]	Rectangular	1	0,0 K (0,05 K)[2]
$\delta_{\Delta T}$	0,0 °C	0,0 K	Normal	1	0,0 K
T_{meas}	-23,0 °C				0,223 K (0,228 K) [a]

[a] The value between brackets is relevant in case the temperature of the laboratory (in which the DAQ systems are located) is 4 K higher or lower than the range of 18 °C to 28 °C.

Based on the standard uncertainties derived at the different conditions, the expanded uncertainties ($U(T)$, k = 2) are derived. In Table A.3, only the case of measuring inside a climate room between 16 °C and 32 °C is shown and includes rounding. The numbers are only valid if the lab temperature (where the DAQ systems are placed) is between 14 °C and 32 °C.

Table A.3 – Expanded uncertainty in measured temperature ($U(T)$, k = 2) at a room temperature in the range of 16 °C to 32 °C and a lab temperature between 14 °C and 32 °C

Measured property at climate room temperature between 16 °C to 32 °C and lab temperature between 14 °C and 32 °C	$u(T_{meas})$	$U(T_{meas})$
Temperatures around −23 °C	0,22 K	0,4 K
Temperatures around 43 °C	0,16 K	0,3 K
Temperatures around 0 °C	0,15 K	0,3 K

A.4 Analysis of each component in the uncertainty formulation, example thermocouple simulator

The main part of this work is to establish the values used in the equation for the measured temperature in Clause A.3. This requires several different investigations, which are too lengthy to include in this example. An example is given for only one of the items in the uncertainty budget: the thermocouple simulator. This is a device calibrated by an external laboratory from which the reference calibration data has been taken from the calibration report.

The thermocouple simulator was calibrated under ISO 17025 by the supplier at the temperatures given in Table A.4.

Table A.4 – Calibration results of the simulator

Temperature [°C]	Deviation [°C]	Uncertainty of measurement (k = 2) [°C]
−60,00	+0,02	0,03
−40,00	+0,02	0,03
−23,00	+0,02	0,02
0,00	+0,02	0,02
25,00	+0,03	0,02
50,00	+0,03	0,02

The uncertainty of the simulator is resulting from the deviation found during the calibration and the uncertainty of the calibration reference system itself. Because the deviation was not adjusted, it is included in the uncertainty budget. Therefore, the resulting uncertainty is (between −23 °C and 50 °C):

$$U\left(t(s)\right) = U\left(\delta_{\text{SIM}}\right) + U\left(\delta_{\text{cal\_set\_up}}\right) = 0{,}03 + 0{,}02 = 0{,}05 \tag{A.2}$$

and, assuming a normal distribution;

$$u\left(t(s)\right) = \frac{U\left(t(s)\right)}{2} = 0{,}025 \tag{A.3}$$

Derivation of $\delta_{\text{A\_SIM}}$:

During calibration of the DAQ systems in the laboratory, the climate room temperature in which the simulator is used is set at 25 °C. The simulator itself is calibrated in accordance with ISO 17025 by the supplier at 25 °C, therefore no budget for uncertainty due to a variation in ambient temperature is required.

$\delta_{\text{A\_SIM}}$ = 0 and $u(\delta_{\text{A\_SIM}})$ = 0

Derivation of $\delta_{\text{D\_SIM}}$:

Next to the calibration results, the manufacturer states a long-term stability of:

U-drift = < 20 ppm/year + 2 μV/year

For a type T thermocouple measuring a temperature difference of 20 K, a voltage of 0,789 mV would be generated. The corresponding drift would be (20 ppm × 0,000 789 / 1 000 000 + 0,000 002) / (0,000 789 / 20 K) = 0,05 °C/year

Based on this, the uncertainty due to drift can be estimated:

$\delta_{\text{D\_SIM}}$ = 0, and assuming a rectangular distribution: $u\left(\delta_{D\_SIM}\right) = \dfrac{0{,}05}{\sqrt{3}} = 0{,}029$.

Annex B
(informative)

Guidance on how to conduct round robin tests for household and similar electrical appliances

B.1 General

It is the responsibility of each standardisation committee testing household and similar electrical appliances to establish the **repeatability** and **reproducibility** of the measurement standards developed.

Results from inter-laboratory comparisons are important for

a) identification of inter-laboratory differences;

b) establishment of the effectiveness and comparability of test or measurement methods;

c) validation of uncertainties;

d) evaluation of the performance of laboratories for specific tests or measurements and monitoring laboratories' continuing performance;

e) identification of problems in laboratories and initiation of actions for improvement which, for example, may be related to inadequate test or measurement procedures, effectiveness of staff training and supervision, or calibration of equipment; and

f) education of participating laboratories based on the outcomes of such comparisons.

The need for ongoing confidence in laboratory performance is not only essential for laboratories and their contractors but also for other interested parties, such as regulators, laboratory accreditation bodies and other organisations that specify requirements for laboratories. ISO/IEC 17011 requires accreditation bodies to take account of laboratories' participation and performance in proficiency testing.

In this regard, **round robin testing** in the past was largely performed by TC59 for the development of measurement procedures for the EU regulation on Labelling and Ecodesign. **Round robin test** results have been widely taken into account in the establishment of regulations, in defining tolerance levels for verification of declared values and/or limits.

This annex is intended to provide a consistent basis for performing **round robin testing**. It gives guidance to all interested parties to determine the respective competence. It provides common ground for reliable statistical data (**repeatability** and **reproducibility** levels, etc.) as needed for regulation purposes (such as Labelling and Ecodesign).

B.2 Scope

This annex provides guidance for carrying out **round robin tests** (RRT) and hence for the determination of levels of **repeatability** (intra-laboratory variability) and **reproducibility** (inter-laboratory variability) for household and similar electrical appliances.

NOTE 1 It is the intention to derive levels of **repeatability** and **reproducibility** and hence make classifications of laboratories.

NOTE 2 An alternative term is "ring testing". The term "proficiency testing" is more general, covering aspects other than derivation of **repeatability** and **reproducibility** values (see ISO/IEC 17043:2010, definition 3.7).

NOTE 3 The results of the **round robin testing** can be used for the evaluation of laboratory performance against pre-established criteria.

This document can also be used to verify the measurement methods, to improve the measurement method, and to qualify laboratories.

It is not applicable for the determination of production variability for a particular product.

General advice on proficiency testing of laboratories is given in ISO/IEC 17043, which can be used in addition to this document.

NOTE 4 The **repeatability** and **reproducibility** levels are important factors for the establishment of uncertainty margins of the measurement methods and for the definition of tolerances levels in verification schemes.

B.3 Process and responsibilities

B.3.1 Process

B.3.1.1 Product to be tested

The product category to be tested should be clearly specified and one or more representative products should be selected. If only one product is selected, it should be representative in the sense that it reflects the typical behaviour and performance of the defined product category. It is recommended that two or more products be tested in order to get an indication of the measurement uncertainty across the range of performance that is likely to be encountered in the market (for example, one product with high and one with low energy/water consumption or performance).

The products to be used for the RRT can be selected either by pre-testing, pre-selection or special production.

Additional sample(s) should be put aside as replacements in case any RRT samples are damaged.

NOTE It can be appropriate to circulate key items of test equipment or other test objects together with the RRT samples.

B.3.1.2 Parameters to be tested

The parameters to be tested should be clearly defined.

Usually, the full parameter set of a measurement procedure should be covered, for example parameters as set out in IEC 60456 concerning washing machines, such as washing performance, consumption values, time, rinsing efficiency. Noise may be seen as a different measurement procedure.

If **repeatability** and **reproducibility** of the measurement standard are to be assessed, all additional materials used for the testing should be as defined in the measurement procedure, and should not be specially selected (examples of such materials in the case of washing machine tests would include test swatches, soils and detergent).

If it is considered likely that the **reproducibility** of results could be affected by variability batch-to-batch or from different suppliers within given tolerances of the test material, this can form part of the RRT. In this case, different batches or different suppliers of material would need to be included in the test design of the RRT.

B.3.1.3 Measurement procedure

The measurement procedure(s) to be used for testing should be clearly defined. RRTs should be based preferably on published IEC standards. For RRTs supporting standardisation work, it can be necessary to use working papers like Committee Draft (CD) or even Document for Comment (DC) documents as the measurement procedure. Alternatively, national, international and/or industrial standards may be used and, where necessary, combinations of more than one measurement method can be used. It is essential, therefore, that clear instructions are given on which version of a measurement standard the RRT is based. If deviations between the standard used for the RRT and a later published standard exist, care should be taken in interpretation of the results of the RRT in relation to the final published standard.

B.3.1.4 RRT procedure

The RRT procedure is based on sending one or more products to different laboratories to be tested according to the defined measurement procedure(s). Therefore, the same sample of the product(s) is forwarded from laboratory to laboratory (serial procedure).

Care should be taken to ensure no damage or change (e.g. aging) occurs to the product during this process. Damage can be limited by ensuring the sample is properly packaged and that it is transported from laboratory to laboratory by a carrier with a proven track record of transporting delicate items.

The aging effect can be reduced using the parallel procedure described below but, in any case, the extent of any aging should wherever possible be determined by re-testing the same product again in the first laboratory after it has gone through all the testing in the other laboratories. If severe changes are observed, the issue should be addressed by the coordinator to the contracting body.

As a second best alternative, more than one sample of the product selected is sent in parallel to the laboratories (parallel procedure). In this case, before the RRT begins, it should be demonstrated that all samples show similar behaviour under test. Again, the samples should, wherever possible, be re-tested by the same laboratory at the end of the RRT to check for any change in behaviour under test.

For calculating reliable figures of the **repeatability** and **reproducibility**, a minimum of five laboratories should participate in an RRT. If more than 10 laboratories take part in an RRT, a parallel procedure combined with a serial procedure can be advisable for time reasons (e.g. samples showing similar behaviour are each sent to five laboratories).

B.3.2 Responsibilities

B.3.2.1 Contracting body

The contracting body is an organisation or individual for which a **round robin testing** is provided through a contractual arrangement The body(ies) which is (are) running and/or financing the RRT should operate in a transparent manner towards all involved parties.

The contracting body should appoint an individual or a team to coordinate the RRT.

B.3.2.2 Coordinator

The coordinator should be on call throughout the testing phase.

The selection of coordinator should be fair, just and transparent. If only one person is coordinating the RRT, he/she should be neutral and independent. For example, he/she should not be employed by a product manufacturer or a test house involved in the RRT. Deviations from this rule can be necessary in individual cases.

Any deviations from the recommendations of this document should be documented by the coordinator and included in the final internal report.

B.3.2.3 Subcontractor

Subcontractors (collaborators) in RRTs should inform the coordinator regularly about progress. The coordinator should be informed about unforeseeable proceedings without any delay.

B.3.2.4 Financing of RRT

The coordinator should establish and agree with the contracting body the financing of the RRT. All costs (e.g. coordinator, subcontractor, product samples to be tested, logistics, test materials, testing) for the RRT are to be defined and agreed before recruiting participant laboratories.

B.4 Testing laboratories

B.4.1 Potential laboratories

A list of potential laboratories should be prepared by the coordinator, in consultation with the contractor and relevant standardisation bodies.

B.4.2 Announcement

B.4.2.1 General

The **round robin test** should be announced publicly together with the qualification criteria as defined in a document called "Qualification of laboratories for verification procedures" (e.g. tender procedure, TC59 working group procedure) so that all laboratories that might be interested have the chance to apply to take part in the RRT.

Potential laboratories may be contacted directly.

B.4.2.2 Questionnaire

The announcement should be accompanied by a questionnaire where the general qualification of the laboratory (equipment, experience, certification, qualification) should be assessed. The laboratories are asked to answer within a fixed time frame.

If there are minimum qualification criteria given to take part in the RRT, interested labs have to confirm fulfilling these qualification criteria as well as their agreement to the financial conditions. (See also B.3.2.4)

B.4.2.3 Assessment of selection of laboratories

An assessment scheme for selecting the laboratories including a defined scoring and minimum requirements for selecting a laboratory should be defined by the organisers before the announcement is sent out.

B.4.3 Selection of laboratories

All laboratories that comply with the minimum requirements and which have confirmed their interest should be allowed to take part in the RRT. If, for practical reasons, participation has to be limited, those laboratories should be chosen which have the highest ranking according to the replies on their questionnaire. If laboratories express their interest to participate, but do not fulfil some minimum requirements, they may take part in the RRT as a learning exercise, but their measurement results should not be included in the final evaluation. They may also be excluded from any financial benefits.

B.4.4 Final list of laboratories

Based on the result of the assessment, the coordinator prepares a list of laboratories which are to participate in the RRT. In consultation with the laboratories, the coordinator establishes a sequence of testing and a timescale so that each laboratory knows when it will receive the RRT samples and when it must forward the samples to the next participating laboratory.

B.5 Transportation of the product

B.5.1 Logistics

The coordinator may contract a specialist company to transport the RRT samples from laboratory to laboratory.

Alternatively, once a laboratory has concluded the test, it may forward the product to the next participating laboratory.

Whatever logistical system is used, it should be emphasised that special care in handling the samples is essential to avoid compromising their performance.

B.5.2 Packaging

Special care is taken with packaging in order to reduce the chance of damage during the transportation. At least the same protection level as given by the packaging of normal production is ensured, e.g. by using the same packaging material.

Packaging instructions is defined if needed. It is recommended to make use of robust wooden boxes. The appliances could be fixed inside the box by the use of soft corner elements (e.g. polystyrene).

B.6 Test

B.6.1 Performance of test

Laboratories should perform the test in accordance with the measurement procedure. They should inform the coordinator immediately if any problems arise.

The coordinator should provide a format in which the measurement results should be reported.

B.6.2 Laboratory visit

If possible/affordable, the coordinator should visit each laboratory while RRT testing is in progress. During the visit, the following should be checked or verified:

– data given in the questionnaire, especially regarding the test equipment;
– calibration procedure documents relating to the test equipment;
– personal qualifications of persons involved in testing;
– compliance with the measurement procedure as specified for the RRT; and
– laboratory qualification or accreditation.

B.6.3 Transmission of result

Once a laboratory has concluded their tests, they send their measurement results to the coordinator. The coordinator stores the results in an anonymous form. At this stage, the coordinator should conduct a preliminary analysis of the results to assess the consistency of the data. If inconsistencies are encountered, these may be resolved through discussion with the laboratory concerned. The other participants should not be informed about the results at this stage.

B.7 Analysis, report and termination

B.7.1 Analysis

The coordinator or a subcontractor analyses the results following this document or other appropriate documents.

Special care should be taken on handling of **outliers**. Obvious **outliers** may be corrected (e.g. typing errors) after consultation with the laboratory concerned. When no clear reason can be assigned to an **outlier** result, it should be kept in the data files. Final evaluation should be done with and without outlying results.

B.7.2 Report

B.7.2.1 Draft report

A draft internal report should be prepared by the coordinator. The draft internal report should include the items described in B.7.2.2. This report should be disseminated to all participating laboratories. The laboratories should be given the opportunity to respond to the draft report.

After this, the coordinator prepares the final internal report incorporating the feedback from the laboratories and disseminates it to all participating laboratories.

B.7.2.2 Content of the internal report

The report should include:

– results from individual laboratories (made anonymous if appropriate);
– discussion of **outliers** (if needed);
– standard deviations for each parameter (with and without **outliers**);
– **repeatability** and **reproducibility** levels for each parameter (with and without **outliers**);
– learning from possible or necessary improvements of standard.

B.7.3 Termination and publication of final external report

The coordinator should submit a statement to all participants informing them that the RRT has been completed.

Elementary results should be made available for third party scrutiny at least in an anonymous way at least within TC 59. RRT data should not be made available to other non-participating parties without the agreement of all participating parties. It is helpful if the coordinator obtains agreement from the participants for this kind of disclosure before starting the RRT.

The final external report should be made public with only general results included so that competitive and sensitive information is not disclosed. The coordinator should report the results to the relevant technical committee of TC 59.

Annex C
(informative)

Example of a round robin test and its analysis

C.1 General

Data from an example **round robin test** for checking the suitability of a measurement method for the determination of the washing performance and the energy consumption of electric household washing machines as specified in IEC 60456:

Test programme: 60 °C cotton

Number of participating laboratories: 5

Number of tests within one laboratory: 5

Appliances used: 1 test appliance

1 reference appliance

C.2 Standard deviations and assessment of repeatability and reproducibility

Table C.1 – Measurement results

Lab. No	Test No	Washing results			Energy consumption	
		Test appliance	Reference appliance	Performance of test appliance	Test appliance	Reference appliance
1	1	266,18	259,85	1,024	1,17	1,95
	2	256,52	263,01	0,975	1,29	2,15
	3	263,50	261,50	1,008	1,30	2,05
	4	264,22	259,88	1,017	1,08	2,00
	5	261,55	263,20	0,994	1,32	2,10
	$\bar{x}$	262,39	261,49	1,004	1,23	2,05
2	1	248,94	242,54	1,026	1,45	1,70
	2	251,42	242,12	1,038	1,25	1,80
	3	245,30	247,32	0,992	1,34	1,90
	4	256,41	249,30	1,029	1,10	1,90
	5	250,81	246,17	1,019	1,34	1,60
	$\bar{x}$	250,58	245,49	1,021	1,30	1,78
3	1	251,00	231,60	1,084	1,04	2,20
	2	242,50	237,00	1,023	1,07	2,20
	3	244,40	241,00	1,014	1,22	2,10
	4	227,50	241,40	0,942	1,08	2,00
	5	241,60	251,10	0,962	1,12	2,10
	$\bar{x}$	241,40	240,42	1,005	1,11	2,12
4	1	282,49	266,82	1,059	1,20	-
	2	276,71	268,59	1,030	1,09	1,81
	3	287,59	271,93	1,058	1,10	1,80
	4	285,33	272,49	1,047	1,14	1,96
	5	278,50	268,87	1,036	1,13	1,90
	$\bar{x}$	282,12	269,74	1,046	1,13	1,87

Lab. No	Test No	Washing results			Energy consumption	
		Test appliance	Reference appliance	Performance of test appliance	Test appliance	Reference appliance
5	1	251,02	242,99	1,033	1,23	2,37
	2	254,85	240,99	1,058	1,21	2,48
	3	249,16	235,85	1,056	1,15	2,50
	4	257,13	239,91	1,072	1,24	2,35
	5	250,08	245,58	1,018	1,22	2,44
	$\bar{x}$	252,45	241,06	1,047	1,21	2,43

Table C.2 – Standard deviations, repeatability and reproducibility

Lab. No	Washing results of test appliance		Washing results of reference appliance		Washing performance of test appliance		Energy consumption			
							test appliance		reference appliance	
	$\bar{x}$	s_L	$\bar{x}$	s_L	$\bar{x}$	s_L	$\bar{x}$	s_L	$\bar{x}$	s_L
Lab 1	262,39	3,68	261,49	1,62	1,004	0,019	1,23	0,10	2,05	0,08
Lab 2	250,58	4,04	245,49	3,10	1,021	0,018	1,30	0,13	1,78	0,13
Lab 3	241,40	8,60	240,42	7,16	1,005	0,056	1,11	0,07	2,12	0,08
Lab 4	282,12	4,55	269,74	2,40	1,046	0,013	1,13	0,04	1,87	0,08
Lab 5	252,45	3,40	241,06	3,63	1,047	0,021	1,21	0,04	2,43	0,07
x_m	257,79	–	251,64	–	1,025	–	1,20	–	2,05	–
s_r		5,22		4,06		0,030		0,08		0,09
Percentage of acceptance interval: [a]						97 %		47 %		
s_R		16,20		13,72		0,034		0,11		0,26
Percentage of acceptance interval: [a]						111 %		60 %		

[a] Acceptance interval for washing performance: 3 %
Acceptance interval for energy: 10 %
Calculation based on values that have not been rounded

Proposed expanded uncertainties (to be decided by the relevant standardisation committee):

Washing performance: 0,07 (abs)
Energy consumption: 20 %