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Interested committees:

Title: Draft BS ISO 5725-6 Accuracy (trueness and precision) of measurement methods and results. Part 6: Use in practice of accuracy values.

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## Introduction

This draft standard is based on national and international discussions. Your comments on this draft are invited and will assist in the preparation of the consequent standard.

For international standards, comments will be reviewed by the relevant UK national committee before sending the consensus UK vote and comments to the international committee, which will then decide appropriate action. If the international standard is approved, it is usual for the text to be published as a British Standard.

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## Template for comments and secretariat observations

|                  |                        |
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| 1  | 2                                          | (3)                          | 4               | 5                                                                                                                                  | (6)                                                                      | 7                                                  |
|----|--------------------------------------------|------------------------------|-----------------|------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------|----------------------------------------------------|
| MB | Clause No./ Subclause No./Annex (e.g. 3.1) | Paragraph/ Figure/Table/Note | Type of comment | Comment (justification for change) by the MB                                                                                       | Proposed change by the MB                                                | Secretariat observations on each comment submitted |
|    | 3.1                                        | Definition 1                 | ed              | Definition is ambiguous and needs clarifying.                                                                                      | Amend to read '...so that the mains connector to which no connection...' |                                                    |
|    | 6.4                                        | Paragraph 2                  | te              | The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK. | Delete reference to UV photometer.                                       |                                                    |



# DRAFT International Standard

## ISO/DIS 5725-6

### Accuracy (trueness and precision) of measurement methods and results —

#### Part 6: Use in practice of accuracy values

*Exactitude (justesse et fidélité) des résultats et méthodes de mesure —*

*Partie 6: Utilisation dans la pratique des valeurs d'exactitude*

ICS: 17.020

ISO/TC 69/SC 6

Secretariat: JISC

Voting begins on:  
**2025-06-16**

Voting terminates on:  
**2025-09-08**

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## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see [www.iso.org/directives](http://www.iso.org/directives)).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see [www.iso.org/patents](http://www.iso.org/patents)).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see [www.iso.org/iso/foreword.html](http://www.iso.org/iso/foreword.html).

This document was prepared by Technical Committee ISO/TC 69, *Applications of Statistical Methods*, Subcommittee SC 6, *Measurement Methods and Results*.

This second edition cancels and replaces the first edition (ISO 5725-6:1994), which has been technically revised. It also incorporates the Technical Corrigendum ISO 5725-6:1994/Cor 1:2001.

The main changes compared to the previous edition are as follows:

- the entire document has been revised to conform to the latest ISO 5725 Parts 1 to 4;
- descriptions related to the control chart have been revised to conform to the ISO 7870 series;
- calculation processes have been more detailed;
- information on the computation related to order statistics has been included in the Annexes.

A list of all parts in the ISO 5725 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at [www.iso.org/members.html](http://www.iso.org/members.html).

## Introduction

**0.1** ISO 5725 uses two terms, "trueness" and "precision", to describe the accuracy of a measurement method. "Trueness" refers to the closeness of agreement between the arithmetic mean of a large number of test results and the true or accepted reference value. "Precision" refers to the closeness of agreement between test results.

**0.2** "Precision" must be considered because tests performed on presumably identical materials in presumably identical circumstances do not generally yield identical results. This is attributed to unavoidable random errors inherent in every measurement procedure; the factors that influence the outcome of a measurement cannot all be completely controlled. In the practical interpretation of measurement data, this variability has to be considered. For instance, the difference between a test result and some specified value may be within the scope of unavoidable random errors, in which case a real deviation from such a specific value has not been established. Similarly, comparing test results from two batches of material will not indicate a fundamental quality difference if the difference between them can be attributed to the inherent variation in the measurement procedure.

**0.3** This Part of 5725, as for other Parts, considers that measurement error can be divided into a component of error attributed to random causes and a component of error which can be attributed to systematic causes. It is understood that some causes of error can lead to a constant error during a particular set of observations, appearing to be systematic for that set of observations, but can lead to a different error for another set of observations. For example, in an interlaboratory study, the laboratory component of bias is a systematic error for each laboratory, but varies randomly when considered across a collection of laboratories. Similarly, within a laboratory, a set of observations over a limited time can be subject to a systematic error from a given cause (such as choice of equipment or operator) which can in principle vary randomly over sets of observations at other times. It is accordingly important to consider possible changes in systematic effects when comparing results taken under different conditions, such as in different laboratories or over longer periods of time within a laboratory.

**0.4** Parts 1 to 5 of ISO 5725 discuss the background and give methods regarding the assessment of the precision (in terms of the repeatability standard deviation and the reproducibility standard deviation) and the trueness (in terms of the various components of bias) of measurements produced by a standard measurement method. Such an assessment would, however, be pointless if there were no practical uses for the results.

**0.5** Given that the accuracy of a measurement method has been established, this part of ISO 5725 applies that knowledge in practical situations to facilitate commercial transactions and to monitor and improve the operational performance of laboratories.

# Accuracy (trueness and precision) of measurement methods and results —

## Part 6: Use in practice of accuracy values

### 1 Scope

**1.1** This document gives some indications of how accuracy data, including trueness and precision data, can be used in various practical situations by:

- a) giving a standard method of calculating the repeatability limit, the reproducibility limit, and other limits to be used in examining the test results obtained by a standard measurement method;
- b) providing a way of checking the acceptability of test results obtained under repeatability or reproducibility conditions;
- c) describing how to assess the stability of results within a laboratory over a period of time, and thus providing a method of "quality control" of the operations within that laboratory;
- d) describing how to assess whether a given laboratory can use a given standard measurement method satisfactorily;
- e) describing how to compare alternative measurement methods.

**1.2** This document is concerned exclusively with measurement methods which yield measurements on a continuous scale and give a single numerical figure as a result. This single figure may be the outcome of a calculation from a set of observations.

**NOTE 1** It is assumed that the estimates of trueness and precision for the method have been obtained in accordance with parts 1 to 5 of ISO 5725.

**NOTE 2** Any additional information regarding the field of application will be given at the beginning of each particular application.

### 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 3534-1, *Statistics — Vocabulary and symbols — Part 1: General statistical terms and terms used in probability*

ISO 3534-2, *Statistics — Vocabulary and symbols — Part 2: Applied statistics*

ISO 3534-3, *Statistics — Vocabulary and symbols — Part 3: Design of experiments*

ISO 5725-1, *Accuracy (trueness and precision) of measurement methods and results — Part 1: General principles and definitions*

ISO 5725-2, *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 5725-3, *Accuracy (trueness and precision) of measurement methods and results — Part 3: Intermediate precision and alternative designs for collaborative studies*

ISO 5725-4, *Accuracy (trueness and precision) of measurement methods and results — Part 4: Basic methods for the determination of the trueness of a standard measurement method*

ISO 7870-2, *Control charts — Part 2: Shewhart control charts*

ISO 7870-4, *Control charts — Part 4: Cumulative sum charts*

### 3 Terms and definitions

For the purposes of this document, the definitions given in ISO 3534-1, ISO 3534-2, ISO 3534-3, and ISO 5725-1 apply.

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

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

### 4 Symbols

|                           |                                                                                                                                              |
|---------------------------|----------------------------------------------------------------------------------------------------------------------------------------------|
| $A$                       | Factor used to calculate the control limits of $\bar{X}$ chart                                                                               |
| $c(n)$                    | Ratio of the standard deviations of the median to the arithmetic mean of $n$ test results                                                    |
| CD                        | Critical difference                                                                                                                          |
| $CR_{0,95}, CR_{0,95}(n)$ | Critical range at the 95 % probability level (for $n$ test results)                                                                          |
| CL                        | Centre line                                                                                                                                  |
| Cov                       | Covariance (Annex)                                                                                                                           |
| CUSUM                     | Cumulative sum control                                                                                                                       |
| $d_2$                     | Factor used to calculate the centre line of a Range chart                                                                                    |
| $D_2$                     | Factor used to calculate the upper control limit of a Range chart                                                                            |
| $D_3$                     | Factor used to calculate the lower control limit of a Range chart                                                                            |
| $E$                       | Expectation (Annex)                                                                                                                          |
| $f$                       | Critical range factor<br>Probability density function of a range (Annex)                                                                     |
| $F_{\gamma}(v_A, v_B)$    | $\gamma$ -quantile of the $F$ distribution with degrees of freedom $v_A$ (numerator) and $v_B$ (denominator), where $0 \leq \gamma \leq 1$ . |
| $g$                       | Density function of order statistics (Annex)                                                                                                 |
| $G$                       | Grubbs' test statistic                                                                                                                       |
| $h$                       | Standardized decision limit of a CUSUM chart                                                                                                 |
| $H$                       | Observed reference shift of a CUSUM chart                                                                                                    |
| $k$                       | Standardized reference value of a CUSUM chart                                                                                                |

|             |                                                                                                                                          |
|-------------|------------------------------------------------------------------------------------------------------------------------------------------|
| $K_1$       | Reference value for the upper side of a CUSUM chart                                                                                      |
| $K_2$       | Reference value for the lower side of a CUSUM chart                                                                                      |
| $L_{CL}$    | Lower control limit                                                                                                                      |
| $m$         | Arbitrary integer (Annex)                                                                                                                |
| $n$         | Number of test results obtained in one laboratory at one level (i.e. per cell)<br>Number of samples (Annex)<br>Arbitrary integer (Annex) |
| $n_i$       | Number of test results obtained in laboratory $i$ at one level (i.e. per cell)                                                           |
| $\bar{n}$   | Arithmetic mean of the number of each laboratory's test results $n_i$ .                                                                  |
| $p$         | Number of laboratories participating in the interlaboratory experiment                                                                   |
| $P$         | Probability (Annex)                                                                                                                      |
| $q$         | Number of levels of the test property in the interlaboratory experiment                                                                  |
| $r$         | Repeatability limit<br>Arbitrary integer (Annex)                                                                                         |
| $R$         | Reproducibility limit                                                                                                                    |
| $R_m$       | Moving range                                                                                                                             |
| RM          | Reference material                                                                                                                       |
| $s$         | Estimate of a standard deviation                                                                                                         |
| $S$         | CUSUM statistic                                                                                                                          |
| $U_{CL}$    | Upper control limit                                                                                                                      |
| Var         | Variance (Annex)                                                                                                                         |
| $w$         | Range<br>Moving range                                                                                                                    |
| $\bar{w}$   | Arithmetic mean of (moving) ranges                                                                                                       |
| $x$         | Test results ( <a href="#">Clause 7</a> )<br>Function argument (Annex)                                                                   |
| $\bar{x}$   | Average of test results ( <a href="#">Clause 7</a> )                                                                                     |
| $X$         | Individual value ( <a href="#">Clause 7</a> )<br>Random variable following a normal distribution (Annex)                                 |
| $\bar{X}$   | Sample (arithmetic) mean of random variables $X_1, X_2, \dots, X_n$ (Annex)                                                              |
| $\tilde{X}$ | Sample median of random variables $X_1, X_2, \dots, X_n$ (Annex)                                                                         |
| $y$         | Test results (Except <a href="#">Clause 7</a> )<br>Function argument (Annex)                                                             |
| $\bar{y}$   | Arithmetic mean of each laboratory's test results (Except <a href="#">Clause 7</a> )                                                     |

|                      |                                                                                                                                                          |
|----------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------|
| $\bar{\bar{y}}$      | Grand mean of test results (Except <a href="#">Clause 7</a> )                                                                                            |
| $z$                  | Probability density function of the standard normal distribution (Annex)                                                                                 |
| $\alpha$             | Probability associated with a critical value of a test statistic, also referred to as a level of significance                                            |
| $\beta$              | Probability associated with a risk of failing to detect                                                                                                  |
| $\delta$             | Laboratory bias                                                                                                                                          |
| $\hat{\delta}$       | Estimate of a laboratory bias                                                                                                                            |
| $\lambda$            | Detectable difference between two laboratory biases                                                                                                      |
| $\mu$                | True value or accepted reference value of a test property                                                                                                |
| $\nu$                | Degree of freedom                                                                                                                                        |
| $\rho$               | Detectable ratio between precision measures of the two methods when the precision is expressed as the repeatability standard deviation                   |
| $\sigma$             | True value of a standard deviation                                                                                                                       |
| $\phi$               | Detectable ratio between precision measures of the two methods when the precision is expressed as the square root of the between-laboratory mean squares |
| $\varphi$            | Inverse function of the cumulative distribution function of the standard normal distribution (Annex)                                                     |
| $\Phi$               | Cumulative distribution function of the standard normal distribution (Annex)                                                                             |
| $\chi^2_\gamma(\nu)$ | $\gamma$ -quantile of the $\chi^2$ distribution with $\nu$ degrees of freedom ( $0 \leq \gamma \leq 1$ ).                                                |

## Subscripts

|        |                                                                                                                                                                                       |
|--------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| $A, B$ | Numbering for measurement methods                                                                                                                                                     |
| $i$    | Identifier for a particular laboratory<br>Identifier for a particular sample (Annex)<br>Index for summation (Annex)                                                                   |
| $j$    | Identifier for a particular trial when the number of levels = 1<br>Identifier for a particular level when the number of levels $\geq 2$<br>Identifier for a particular sample (Annex) |
| $k$    | Identifier for a trial when the number of levels $\geq 2$                                                                                                                             |
| $L$    | Between-laboratory (interlaboratory)                                                                                                                                                  |
| Lower  | Lower side                                                                                                                                                                            |
| $P$    | Probability                                                                                                                                                                           |
| $M$    | Between-test-sample                                                                                                                                                                   |
| min    | Minimum value                                                                                                                                                                         |
| max    | Maximum value                                                                                                                                                                         |

|                                    |                                                                                                                                                                                                                                                               |
|------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| $n$                                | Number of test results obtained in one laboratory at one level (i.e. per cell)                                                                                                                                                                                |
| $r$                                | Repeatability                                                                                                                                                                                                                                                 |
| $R$                                | Reproducibility                                                                                                                                                                                                                                               |
| $t$                                | Identifier for time                                                                                                                                                                                                                                           |
| Upper                              | Upper side                                                                                                                                                                                                                                                    |
| $W$                                | Within-laboratory (intralaboratory)                                                                                                                                                                                                                           |
| 0                                  | Given reference value                                                                                                                                                                                                                                         |
| 1, 2, 3, ...                       | For test results, numbering in the order of obtaining them; for other cases (laboratories), as arbitrary identifiers                                                                                                                                          |
| (1), (2), (3), ...                 | For test results, (1), (2), (3), ... denote the 1 <sup>st</sup> , 2 <sup>nd</sup> , 3 <sup>rd</sup> ,... etc. order statistic, that is, the 1 <sup>st</sup> , 2 <sup>nd</sup> , 3 <sup>rd</sup> ,... etc. value numbered in the order of increasing magnitude |
| (1  $n$ ), (2  $n$ ), (3  $n$ )... | Same as (1), (2), (3),... etc., but emphasize the sample size is $n$ (Annex)                                                                                                                                                                                  |

## 5 Determination of limits

### 5.1 Repeatability and reproducibility limits

**5.1.1** In ISO 5725-2, attention has been focused on estimating the standard deviations associated with operations under repeatability or reproducibility conditions. However, normal laboratory practice requires examination of the difference(s) observed between two (or more) test results, either within a single laboratory or between two different laboratories. For this purpose, some measure akin to a critical difference is required rather than a standard deviation.

**5.1.2** When a quantity is based on sums or differences of  $n$  independent estimates, and each has a standard deviation  $\sigma$ , that resultant quantity will have a standard deviation  $\sigma\sqrt{n}$ . Because the reproducibility limit ( $R$ ) or repeatability limit ( $r$ ) is for differences between two test results, the associated standard deviation is  $\sigma\sqrt{2}$ . In normal statistical practice, the critical difference for examining the difference between these two values is  $f$  times this standard deviation, that is,  $f\sigma\sqrt{2}$ . The value of  $f$  (the critical range factor) depends on the probability level to be associated with the critical difference and on the shape of the underlying distribution. For the reproducibility and repeatability limits, the probability level is specified as 95 %, and throughout the analysis in ISO 5725, the underlying distribution is assumed to be approximately normal. For a normal distribution at the 95 % probability level,  $f$  is 1,96 and then  $f\sqrt{2}$  is 2,77. As this part of ISO 5725 aims to give some simple "rule of thumb" to be applied by nonstatisticians when examining the test results, it seems reasonable to use a rounded value of 2,8 instead of  $f\sqrt{2}$ .

**5.1.3** As stated above, the process of estimating precision leads to estimates of the true standard deviations, but the true standard deviations remain unknown. Therefore, in statistical practice, they should be denoted by  $s$  rather than  $\sigma$ . However, if the procedures in ISO 5725-1 and ISO 5725-2 are followed, then these estimates will be based on an appreciable number of test results and provide the best information on the true standard deviations. In the applications described later in this document, the symbol  $s$  (estimate of a standard deviation) is used for estimates of these standard deviations based on more limited data. Therefore, it is considered best to use the symbol  $\sigma$  to denote the values obtained from a full precision experiment and treat them as the true standard deviations to be used for comparison with other estimates ( $s$ ).

**5.1.4** In view of 5.1.1 to 5.1.3, when examining two single test results obtained under repeatability or reproducibility conditions, the comparison shall be made with the repeatability limit  $r=2,8\sigma_r$  or the reproducibility limit  $R=2,8\sigma_R$ .

## 5.2 Comparisons based on more than or equal to two values

### 5.2.1 Two groups of measurements in one laboratory

It is assumed that, in one laboratory under repeatability conditions, two groups of measurements are performed with the first and second groups of  $n_1$  test results giving an arithmetic mean of  $\bar{y}_1$  and  $n_2$  test results giving an arithmetic mean of  $\bar{y}_2$ , respectively. Then, the standard deviation of  $(\bar{y}_1 - \bar{y}_2)$  is

$$\sigma = \sqrt{\sigma_r^2 \left( \frac{1}{n_1} + \frac{1}{n_2} \right)} \quad (1)$$

and the critical difference for  $|\bar{y}_1 - \bar{y}_2|$  is

$$CD = f\sigma = (f\sqrt{2}) \cdot \left( \frac{\sigma}{\sqrt{2}} \right) = 2,8\sigma_r \sqrt{\frac{1}{2n_1} + \frac{1}{2n_2}} \quad (2)$$

at the 95 % probability level.

NOTE If  $n_1 = n_2 = 1$ , then CD reduces to  $r = 2,8\sigma_r$ , as expected.

### 5.2.2 Two groups of measurements in two laboratories

It is assumed that the first laboratory obtains  $n_1$  test results to give an arithmetic mean of  $\bar{y}_1$ , while the second laboratory obtains  $n_2$  test results to give an arithmetic mean of  $\bar{y}_2$ , in each case under repeatability conditions. Then the standard deviation of  $(\bar{y}_1 - \bar{y}_2)$  is

$$\begin{aligned} \sigma &= \sqrt{\left( \sigma_L^2 + \frac{1}{n_1} \sigma_r^2 \right) + \left( \sigma_L^2 + \frac{1}{n_2} \sigma_r^2 \right)} \\ &= \sqrt{2\sigma_L^2 + \sigma_r^2 \left( \frac{1}{n_1} + \frac{1}{n_2} \right)} \\ &= \sqrt{2(\sigma_L^2 + \sigma_r^2) - 2\sigma_r^2 \left( 1 - \frac{1}{2n_1} - \frac{1}{2n_2} \right)} \\ &= \sqrt{2\sigma_R^2 - 2\sigma_r^2 \left( 1 - \frac{1}{2n_1} - \frac{1}{2n_2} \right)} \end{aligned} \quad (3)$$

and the critical difference for  $|\bar{y}_1 - \bar{y}_2|$  is

$$\begin{aligned} CD &= f\sigma = (f\sqrt{2}) \cdot \left( \frac{\sigma}{\sqrt{2}} \right) \\ &= 2,8 \sqrt{\sigma_R^2 - \sigma_r^2 \left( 1 - \frac{1}{2n_1} - \frac{1}{2n_2} \right)} \\ &= \sqrt{(2,8\sigma_R)^2 - (2,8\sigma_r)^2 \left( 1 - \frac{1}{2n_1} - \frac{1}{2n_2} \right)} \end{aligned} \quad (4)$$

at the 95 % probability level.

NOTE If  $n_1 = n_2 = 1$ , then CD reduces to  $R = 2,8\sigma_R$ , as expected.

### 5.2.3 Comparison with a reference value for one laboratory

It is assumed that  $n$  test results are obtained under repeatability conditions within one laboratory, which gives an arithmetic mean of  $\bar{y}$ . If there is no specific knowledge of the laboratory component of bias, the comparison with a given reference value  $\mu_0$  shall be made by using a standard deviation of  $(\bar{y} - \mu_0)$ ,

$$\begin{aligned}\sigma &= \sqrt{\sigma_L^2 + \frac{1}{n}\sigma_r^2} \\ &= \frac{1}{\sqrt{2}} \sqrt{2(\sigma_L^2 + \sigma_r^2) - 2\sigma_r^2 \left(1 - \frac{1}{n}\right)} \\ &= \sqrt{\sigma_R^2 - \sigma_r^2 \left(\frac{n-1}{n}\right)},\end{aligned}\tag{5}$$

Then, the critical difference for  $|\bar{y} - \mu_0|$  is

$$\begin{aligned}\text{CD} &= f\sigma = (f\sqrt{2}) \cdot \left(\frac{\sigma}{\sqrt{2}}\right) \\ &= 2,8 \frac{1}{\sqrt{2}} \sqrt{\sigma_R^2 - \sigma_r^2 \left(\frac{n-1}{n}\right)} \\ &= \frac{1}{\sqrt{2}} \sqrt{(2,8\sigma_R)^2 - (2,8\sigma_r)^2 \left(\frac{n-1}{n}\right)}\end{aligned}\tag{6}$$

at the 95 % probability level.

### 5.2.4 Comparison with a reference value for more than two laboratories

It is assumed that  $p$  laboratories have obtained  $n_i$  test results with the arithmetic means of  $\bar{y}_i$  (in each case under repeatability conditions) and the grand mean  $\bar{\bar{y}}$  is computed by

$$\bar{\bar{y}} = \frac{1}{p} \sum_{i=1}^p \bar{y}_i\tag{7}$$

If this grand mean is to be compared with a reference value  $\mu_0$ , then the standard deviation of  $(\bar{\bar{y}} - \mu_0)$  is

$$\begin{aligned}\sigma &= \sqrt{\frac{1}{p}\sigma_L^2 + \frac{1}{p^2}\sigma_r^2 \sum_{i=1}^p \frac{1}{n_i}} \\ &= \frac{1}{\sqrt{2p}} \sqrt{2(\sigma_L^2 + \sigma_r^2) - 2\sigma_r^2 + \frac{2\sigma_r^2}{p} \sum_{i=1}^p \frac{1}{n_i}} \\ &= \frac{1}{\sqrt{p}} \sqrt{\sigma_R^2 - \sigma_r^2 \left(1 - \frac{1}{p} \sum_{i=1}^p \frac{1}{n_i}\right)}\end{aligned}\tag{8}$$

and the critical difference for  $|\bar{\bar{y}} - \mu_0|$  is

$$\text{CD} = f\sigma = (f\sqrt{2}) \cdot \left(\frac{\sigma}{\sqrt{2}}\right)$$

$$\begin{aligned}
&= 2,8 \frac{1}{\sqrt{2p}} \sqrt{\sigma_R^2 - \sigma_r^2 \left( 1 - \frac{1}{p} \sum_{i=1}^p \frac{1}{n_i} \right)} \\
&= \frac{1}{\sqrt{2p}} \sqrt{(2,8\sigma_R)^2 - (2,8\sigma_r)^2 \left( 1 - \frac{1}{p} \sum_{i=1}^p \frac{1}{n_i} \right)} \quad (9)
\end{aligned}$$

at the 95 % probability level.

### 5.2.5 Summarising the outcome of a comparison

If the absolute difference exceeds the appropriate limit as given in the preceding clauses, then the difference shall be considered significant at the 95 % level of confidence.

## 6 Methods for checking the acceptability of test results and determining the final quoted result

### 6.1 General

**6.1.1** The checking method described in this clause should be applied only to the case where the measurement was carried out according to a measurement method which has been standardized and whose standard deviations,  $\sigma_r$  and  $\sigma_R$ , are known. Therefore, when the range of  $n$  test results exceeds the appropriate limit, as given in [clause 5](#), it is considered that some or all of the  $n$  test results are aberrant. It is recommended that the cause of the aberrant result(s) should be investigated from a technical point of view. However, it may be necessary for commercial reasons to obtain some acceptable value, and in such cases, the test results shall be treated according to the stipulations of this clause.

**6.1.2** This clause has been prepared on the assumptions that the test results were obtained under repeatability and reproducibility conditions and that the probability level to be used is 95 %. If intermediate conditions (see ISO 5725-3) were in force, then it is necessary to replace  $\sigma_r$  by the appropriate intermediate measure.

**6.1.3** In some cases where the procedures described in [subclause 6.2](#) lead to the median being quoted as the final result, it might be better to abandon the data.

### 6.2 Methods for checking the acceptability of test results obtained under repeatability conditions

#### 6.2.1 Single test result

It is not common in commercial practice to obtain only one test result. When only one test result is obtained, it is impossible to make an immediate statistical test of the acceptability of that test result with respect to the given repeatability measure. If there is any suspicion that the test result may not be correct, then a second test result should be obtained. The availability of two test results leads to the more common practice described below.

## 6.2.2 Two test results to start with

### 6.2.2.1 General

Two test results should be obtained under repeatability conditions. The absolute difference between the two test results should then be compared with the repeatability limit  $r = 2,8\sigma_r$ .

NOTE In [subclauses 6.2.2.2](#) and [6.2.2.3](#), reference made to expensive or inexpensive measurements should be interpreted not only in financial terms but also in terms of whether the measurement is complex, troublesome, and time-consuming.

### 6.2.2.2 Case where obtaining test results is inexpensive

If the absolute difference between the two test results does not exceed  $r$ , then both are considered acceptable, and the final quoted result should be the arithmetic mean of the two test results. If the absolute difference does exceed  $r$ , then the laboratory should obtain two further test results.

If the range ( $y_{\max} - y_{\min}$ ) of the four test results is less than or equal to the critical range at the 95 % probability level for  $n=4$ ,  $CR_{0,95}(4)$ , then the arithmetic mean of the four test results should be reported as the final quoted result. The critical range is computed by

$$CR_{0,95}(n) = f(n)\sigma_r, \quad (10)$$

where  $f(n)$  is a critical range factor. [Table 1](#) lists the values of  $f(n)$  for  $n=2$  to 40 and selected values for  $n=45$  to 100. If the range of the four test results is greater than the critical range for  $n=4$ , then the laboratory should report the test results may be unacceptable and may use the median of the three test results as the final quoted result

[Figure 1](#) summarises this procedure in a flowchart.

NOTE [Annex A](#) provides a drive procedure of the values in [Table 1](#).

### 6.2.2.3 Case where obtaining test results is expensive

If the absolute difference between the two test results does not exceed  $r$ , then both are considered acceptable, and the final quoted result should be the arithmetic mean of the two test results. If the absolute difference does exceed  $r$ , then a decision on one of the following three cases a), b), and c) shall be made.

#### a) Case where it is impossible to obtain a third test result

The laboratory should report the test results may be unacceptable and may use the median of the two test results as the final quoted result.

[Figure 2](#) summarises this procedure in a flowchart.

#### b) Case where it is possible to obtain a third test result, but obtaining a fourth one is impossible.

The laboratory should obtain a third test result. If the range ( $y_{\max} - y_{\min}$ ) of the three test results is less than or equal to the critical range at the 95 % probability level for  $n=3$ ,  $CR_{0,95}(3)$ , then the arithmetic mean of the three test results should be reported as the final quoted result. If the range of the three test results is greater than  $CR_{0,95}(3)$ , then the laboratory should report the test results may be unacceptable and may use the median of the three test results as the final quoted result.

[Figure 3](#) summarises this procedure in a flowchart.

#### c) Case where it is possible to obtain third and fourth test results

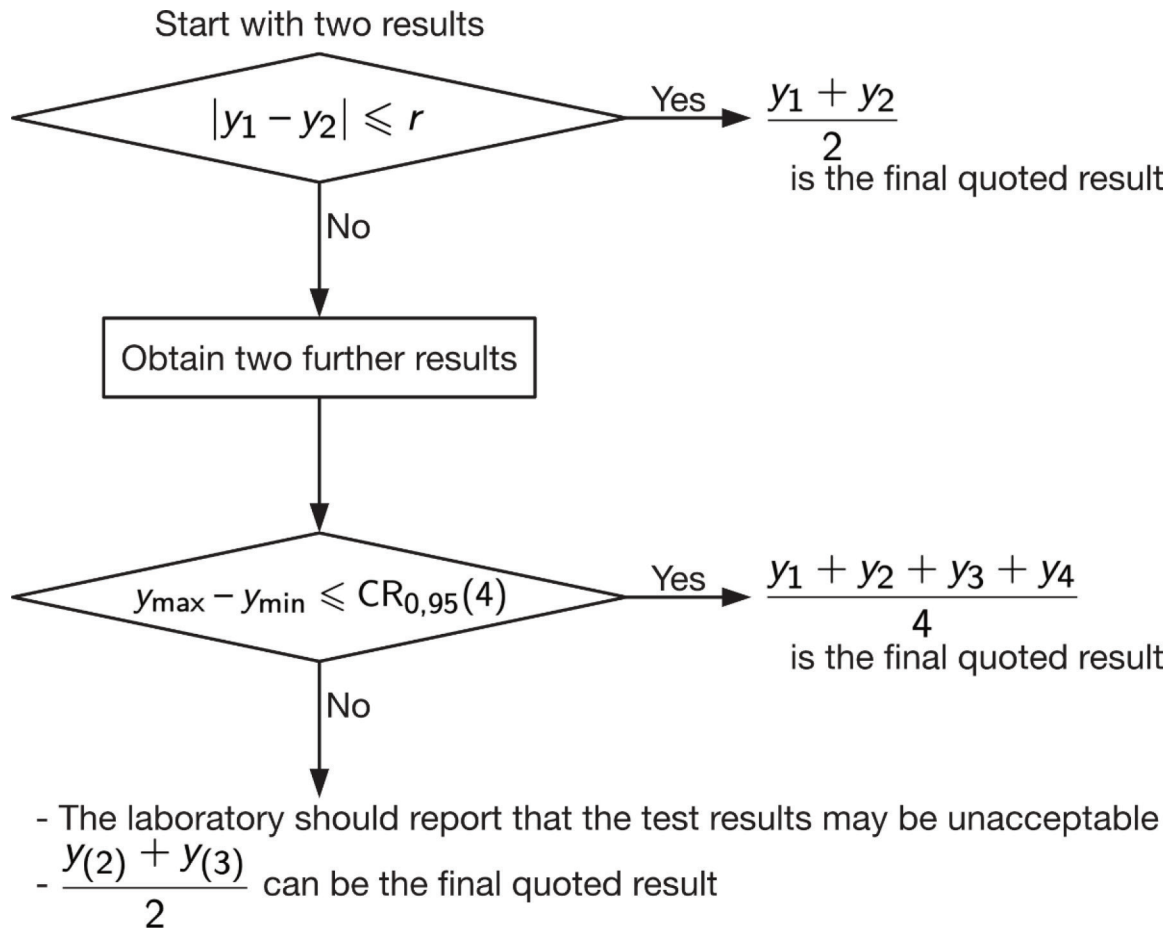
The laboratory should obtain a third test result. If the range ( $y_{\max} - y_{\min}$ ) of the three test results is less than or equal to  $CR_{0,95}(3)$ , then the arithmetic mean of the three test results should be reported as the final

quoted result. If the range of the three test results is greater than  $CR_{0,95}(3)$ , then the laboratory should obtain a fourth test result. If the range  $(y_{\max} - y_{\min})$  of the four test results is equal to or less than  $CR_{0,95}(4)$ , then the arithmetic mean of the four test results should be reported as the final quoted result; while if the range of the four test results is greater than  $CR_{0,95}(4)$ , then the laboratory should report the test results may be unacceptable and may use the median of the four test results as the final quoted result.

[Figure 4](#) summarises this procedure in a flowchart.

**Table 1 — Critical range factors,  $f(n)$**

| $n$                                                                                                                                                                                                                                                                                                                                                | $f(n)$ |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------|
| 2                                                                                                                                                                                                                                                                                                                                                  | 2,8    |
| 3                                                                                                                                                                                                                                                                                                                                                  | 3,3    |
| 4                                                                                                                                                                                                                                                                                                                                                  | 3,6    |
| 5                                                                                                                                                                                                                                                                                                                                                  | 3,9    |
| 6                                                                                                                                                                                                                                                                                                                                                  | 4,0    |
| 7                                                                                                                                                                                                                                                                                                                                                  | 4,2    |
| 8                                                                                                                                                                                                                                                                                                                                                  | 4,3    |
| 9                                                                                                                                                                                                                                                                                                                                                  | 4,4    |
| 10                                                                                                                                                                                                                                                                                                                                                 | 4,5    |
| 11                                                                                                                                                                                                                                                                                                                                                 | 4,6    |
| 12                                                                                                                                                                                                                                                                                                                                                 | 4,6    |
| 13                                                                                                                                                                                                                                                                                                                                                 | 4,7    |
| 14                                                                                                                                                                                                                                                                                                                                                 | 4,7    |
| 15                                                                                                                                                                                                                                                                                                                                                 | 4,8    |
| 16                                                                                                                                                                                                                                                                                                                                                 | 4,8    |
| 17                                                                                                                                                                                                                                                                                                                                                 | 4,9    |
| 18                                                                                                                                                                                                                                                                                                                                                 | 4,9    |
| 19                                                                                                                                                                                                                                                                                                                                                 | 5,0    |
| 20                                                                                                                                                                                                                                                                                                                                                 | 5,0    |
| NOTE The critical range factor $f(n)$ is the 95 % quantile of the distribution of $(y_{\max} - y_{\min})/\sigma$ , where $y_{\max}$ and $y_{\min}$ are the maximum and minimum values, respectively, in a sample of size $n$ from a normal distribution with standard deviation $\sigma$ . Further details can be found in <a href="#">Annex A</a> |        |

**Key**

- $y_{(2)}$  second smallest result
- $y_{(3)}$  third smallest result

**Figure 1 — Method for checking the acceptability of test results, obtained under repeatability conditions, when two test results are obtained to start with and obtaining test results is inexpensive: [Subclause 6.2.2.2](#)**

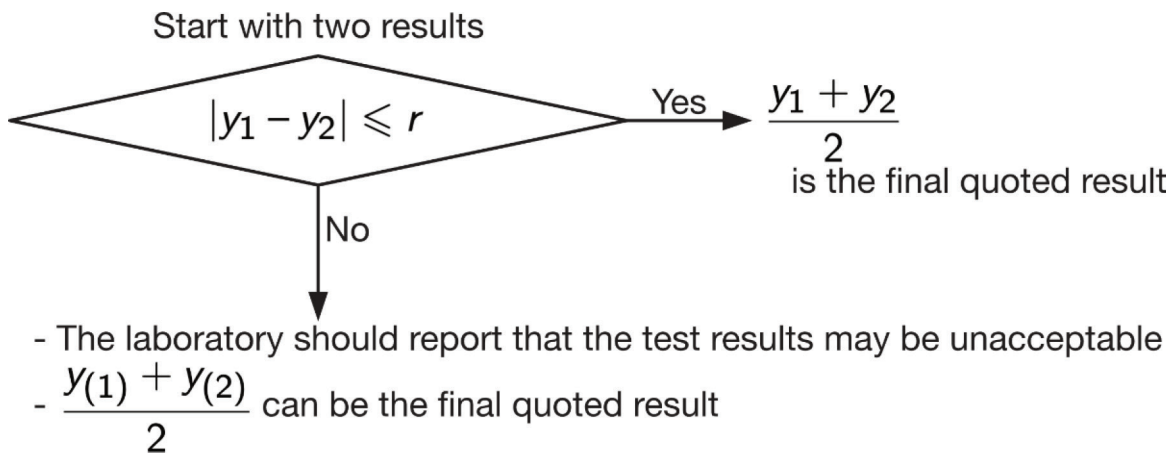
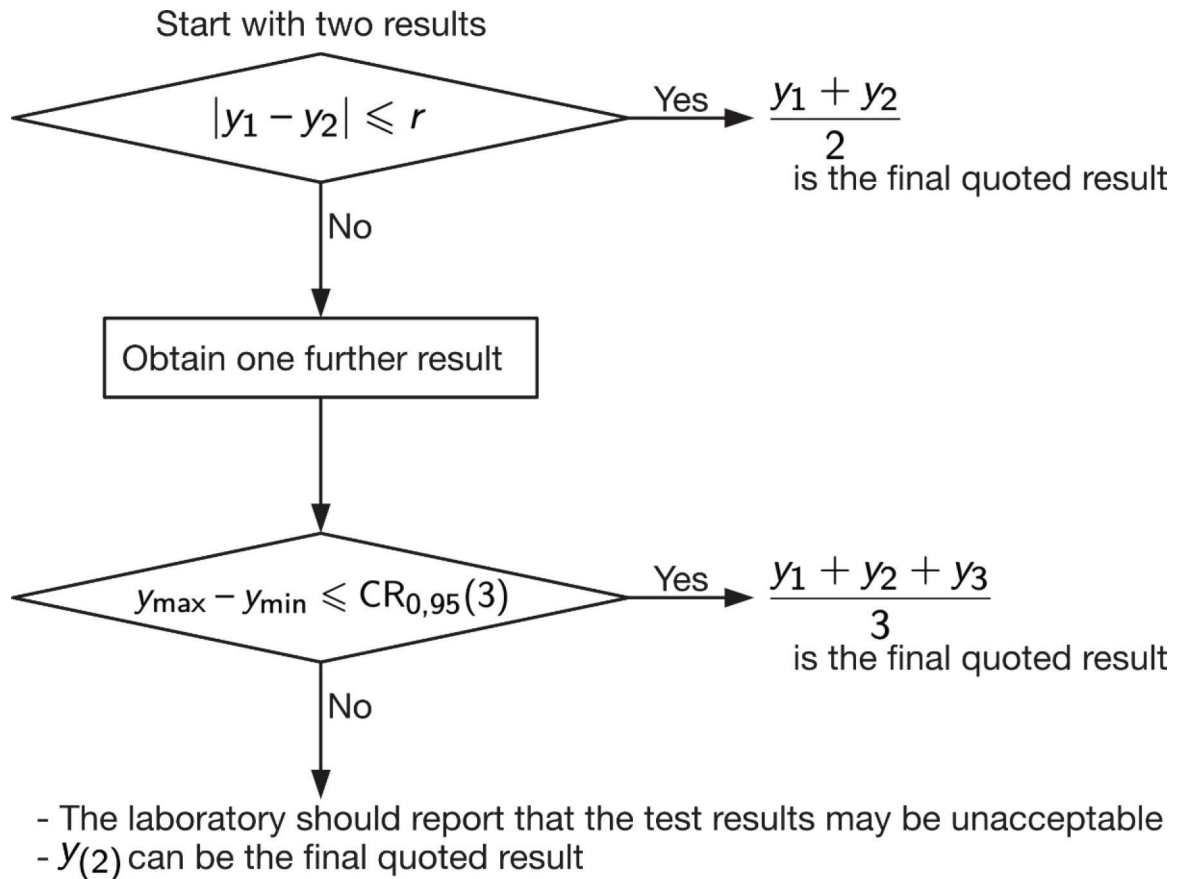
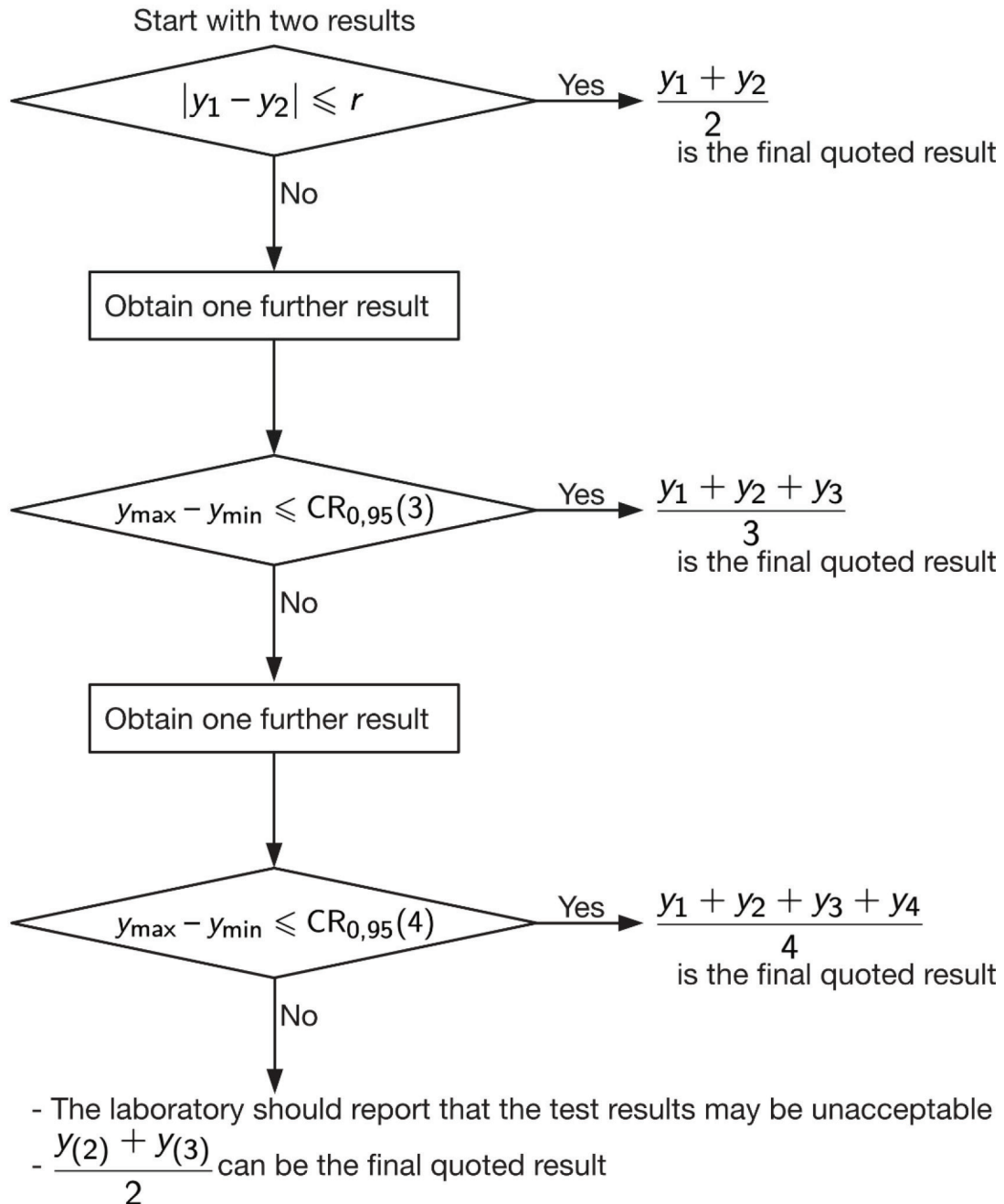


**Figure 2 — Method for checking the acceptability of test results, obtained under repeatability conditions, when two test results are obtained to start with and obtaining test results is expensive. Case a) of [subclause 6.2.2.3](#): it is impossible to obtain a third test result.**

**Key**

$y_{(2)}$  second smallest result

**Figure 3 — Method for checking the acceptability of test results, obtained under repeatability conditions, when two test results are obtained to start with and obtaining test results is expensive. Case b) of [subclause 6.2.2.3](#): it is possible to obtain a third test result, but obtaining a fourth one is impossible.**

**Key**

- $y_{(2)}$  second smallest result  
 $y_{(3)}$  third smallest result

**Figure 4 — Method for checking the acceptability of test results, obtained under repeatability conditions, when two test results are obtained to start with and obtaining test results is expensive: Case c) of [subclause 6.2.2.3](#): it is possible to obtain third and fourth test results.**

### 6.2.3 More than two test results to start with

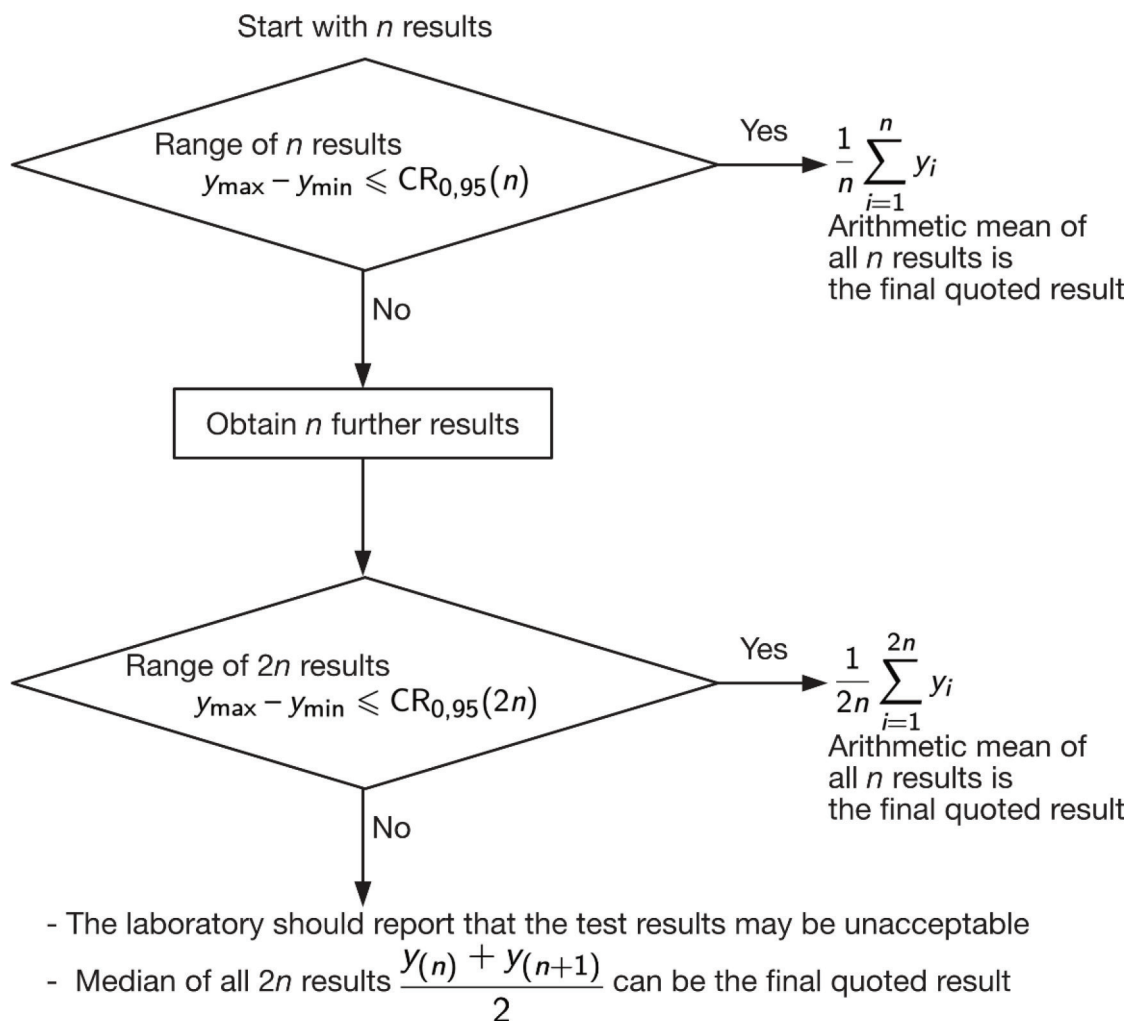
It is sometimes practical to start with more than two test results. The method for obtaining the final quoted result under repeatability conditions for the cases where  $n > 2$  is similar to the case where  $n = 2$ .

The range ( $y_{\max} - y_{\min}$ ) of the test results is compared with the critical range  $CR_{0,95}(n)$ , calculated by (10). If the range does not exceed the critical range, then the arithmetic mean of all the  $n$  test results is used as the final quoted result; while, if the range does exceed the critical range  $CR_{0,95}(n)$ , then a decision on one of the cases A, B, or C, given in Figures 4 to 6, shall be made to obtain the final quoted result.

Cases A and B correspond to the cases where obtaining test results is inexpensive and expensive, respectively. Case C is an alternative, which is recommended when the starting number of test results is five or more and where obtaining each test result is inexpensive, or when the starting number of test results is four or more and where obtaining each test result is expensive.

For inexpensive measurements, the difference between Cases A and C is that Case A requires  $n$  further measurements, whereas Case C requires less than half of that number of further measurements. The decision will depend on the size  $n$  and the ease of performing the measurements.

For expensive measurements, the difference between Cases B and C is that Case C requires further measurements, whereas in Case B, no further measurements are carried out. Case B shall only be considered where the performance of further measurements is so expensive as to be prohibitive.



#### Key

- $y_{(2)}$  second smallest result
- $y_{(3)}$  third smallest result

**Figure 5 — Case A: Method for checking the acceptability of test results, obtained under repeatability conditions, when  $n$  test results are obtained to start with and obtaining test results is inexpensive**