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Capability of detection —

Part 3: Methodology for determination of the critical value for the response variable when no calibration data are used

Capacité de détection —

Partie 3: Méthodologie pour déterminer la valeur critique d'une variable de réponse lorsque aucun étalonnage n'est utilisé

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Foreword

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The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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ISO 11843-3 was prepared by Technical Committee ISO/TC 69, *Applications of statistical methods*, Subcommittee SC 6, *Measurement methods and results*.

ISO 11843 consists of the following parts, under the general title *Capability of detection*:

— *Part 1: Terms and definitions*

— *Part 2: Methodology in the linear calibration case*

— *Part 3: Methodology for determination of the critical value for the response variable when no calibration data are used*

— *Part 4: Methodology for comparing the minimum detectable value with a given value*

Introduction

An ideal requirement for the capability of detection with respect to a selected state variable would be that the actual state of every observed system can be classified with certainty as either equal to or different from its basic state. However, due to systematic and random variations, this ideal requirement cannot be satisfied because:

— In reality, all reference states, including the basic state, are never known in absolute terms of the state variable. Hence, all states can only be characterized correctly in terms of differences from the basic state, i.e. in terms of the net state variable.

  NOTE In ISO Guide 30 and in ISO 11095, no distinction is made between the state variable and the net state variable. As a consequence, in those two documents reference states are — without justification — assumed to be known with respect to the state variable.

— Furthermore, the calibration and the processes of sampling and sample preparation add random variation to the measurement results.

In this part of ISO 11843, the symbol α is used for the probability of detecting (erroneously) that a system is not in the basic state when it is in the basic state.

Capability of detection —

Part 3:
Methodology for determination of the critical value for the response variable when no calibration data are used

1 Scope

This part of ISO 11843 gives a method of estimating the critical value of the response variable from the mean and standard deviation of repeated measurements of the reference state in certain situations (see 5.1) in which the value of the net state variable is zero, for all reasonable and foreseeable purposes. Hence, it can be decided whether values of the response variable in an actual state (or test sample) are above the range of values attributable to the reference state.

General procedures for determination of critical values of the response variable and the net state variable and of the minimum detectable value have been given in ISO 11843-2. Those procedures are applicable in situations in which there is relevant straight-line calibration and the residual standard deviation of the measured responses is either constant or is a linear function of the net state variable. The procedure given in this part of ISO 11843 for the determination of the critical value of the response variable only is recommended for situations in which no calibration data are used. The distribution of data is assumed to be normal or near-normal.

The procedure given in this part of ISO 11843 is recommended for situations in which it is difficult to obtain a large amount of the actual states although a large amount of the basic state can be prepared.

2 Normative references

The following referenced documents are indispensable for the application 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: Probability and general statistical terms*

ISO 3534-2, *Statistics — Vocabulary and symbols — Part 2: Statistical quality control*

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

ISO 5479:1997, *Statistical interpretation of data — Tests for departure from normal distribution*

ISO 5725-2:1994, *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 11095:1996, *Linear calibration using reference materials*

ISO 11843-1:1997, *Capability of detection — Part 1: Terms and definitions*

ISO 11843-2:2000, *Capability of detection — Part 2: Methodology in the linear calibration case*

ISO Guide 30, *Terms and definitions used in connection with reference materials*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 3534 (all parts), ISO Guide 30, ISO 5479, ISO 5725-2, ISO 11095 and ISO 11843-1 apply.

4 Experimental design

4.1 General

The measurement method is assumed to be standardized and known to have been calibrated for measurements of a similar type, although calibration under the specific conditions being studied and at very low levels of the net state variable has not been undertaken or is not possible. The same complete measurement method shall be used for all replicated measurements of the reference state in which the state variable is zero as well as for actual states (test samples) within the measurement series for which a critical value of the response variable is required.

Measurements of actual states shall be randomized among the measurements of the basic state.

Negative values of the response variable shall not be discarded or altered if these arise. For example, negative values shall not be replaced by zeros.

4.2 Choice of the reference state in which the value of the net state variable is zero

One of the assumptions in the procedure described in this part of ISO 11843 is that the value of the net state variable is zero in the reference state chosen. The certainty that can be expected in relation to such an assertion is discussed in ISO 11843-2:2000, Subclause 4.1: in reality, reference states are not known in absolute terms of the state variable but only in terms of differences from a (hypothetical) basic state. For this part of ISO 11843, it is sufficient for the reference level to be well below that likely to be measured by the method being used.

In cases in which the basic state is represented by a preparation of a reference material, the composition should be as close as possible to the composition of the material to be measured, i.e. in analytical chemistry the blank matrix material chosen should be very similar in every way to, if not identical with, the samples being examined in that measurement series. Influences due to the presence of other substances or elements, or due to the physical state of samples, can be highly significant. In particular, when solutions are being investigated, the use of pure solvents rather than the solvent extracts normally encountered in the measurement method is unacceptable.

4.3 Replication

4.3.1 Number of replications, J

The response from the method used on the basic state shall be measured for a sufficient number of replicates J of the entire procedure so as to give a good estimate of the mean and of the standard deviation. It is important to have sufficient data to examine the distribution of data to see whether the response variable is normally, or near-normally, distributed. About 30 measurements should usually ensure that the estimate of the standard deviation will not differ more than 30 % from the true standard deviation with approximately 95 % probability.

NOTE In some situations, it is not possible to perform the number of measurements outlined above because of constraints on the amount of material available or for other reasons. In such situations, the estimate of the standard deviation obtained is markedly uncertain. When such an estimate s (see s_b in 5.2) of a true standard deviation σ is to be made, conclusions can be drawn as to the range about the interval based on s within which the estimate of σ can be expected to lie with prespecified probability $1 - \alpha$. This is a statistical problem usually solved (if assumption of normality is valid and s is the sample standard deviation) by the use of the chi-squared distribution for the number of results on which the estimate of s was based to give a confidence interval for the value of σ of

$$s\sqrt{\frac{\nu}{\chi^2_{1-\frac{\alpha}{2}}(\nu)}} < \sigma < s\sqrt{\frac{\nu}{\chi^2_{\frac{\alpha}{2}}(\nu)}}$$

where $\nu = J - 1$, values of quantiles of χ^2-distribution are obtainable from standard tables and α is as defined in the introduction.

Replications of measurements K on the actual states (test samples) using the entire method will lower the critical value of the response variable to some extent [see Equation (4)], although cost constraints will have to be carefully considered.

4.3.2 Uniformity of replication

When taking samples of the basic state in order to measure the response variable, it is essential to follow in every way the sampling procedure in the overall method.

If standard reference materials are available, they should be used because their homogeneity will have been carefully studied.

The possibilities of some surface phenomena, of electrostatic effects, of settling-out, etc., giving non-identical samples should always be borne in mind.

4.3.3 Possible disturbing factors

Variation of possible disturbing factors during the runs should be minimized, as outlined in ISO 11843-2:2000, Subclause 4.1.

5 Computation of the critical value of the response variable y_c

5.1 Basic method

ISO 11843-1 defines the critical value y_c as the value of the response variable y such that, if it is exceeded, the decision will be made that the system is not in the basic state. The critical value is chosen so that, when the system is in the basic state, this decision will be made with only a small probability α. In other words, the critical value is the minimum significant value of a measurement or signal, applied as a discriminator against background (noise).

The decision "detected" or "not detected" is made by comparison of the arithmetic mean of the determinations obtained for the actual state $\bar{y}_a$ with the critical value y_c of the respective distribution. The probability that the arithmetic mean of measured values $\bar{y}_a$ exceeds the critical value y_c for the distribution in the basic state ($x = 0$) should be less than or equal to an appropriate pre-selected probability α.

The critical value y_c of the response variable can be expressed generally as follows:

$$P(\bar{y}_a > y_c \mid x = 0) \leqslant \alpha \tag{1}$$

NOTE $P(\bar{y}_a > y_c \mid x = 0)$ is the probability that $\bar{y}_a > y_c$ under the condition that $x = 0$.

The definition may be stated as an equality, although the inequality accommodates discrete distributions, such as the Poisson distribution, for which not all values of α are possible.

If

a) y is normally distributed with standard deviation σ_0,

b) samples of actual states are as homogeneous as possible,

c) the measurements are unbiased,

the critical value of the response variable is given by the following simplified expression of Equation (1):

$$y_c = \bar{y}_b \pm z_{1-\alpha}\,\sigma_0\sqrt{\frac{1}{J}+\frac{1}{K}} \quad (2)$$

where

$z_{1-\alpha}$ represents the $(1-\alpha)$-quantile of the standard normal variable;

σ_0 is the standard deviation of the net signal (or concentration) under the null hypothesis (true value $x = 0$);

J is the number of replicate determinations of the basic state;

$\bar{y}_b$ is the arithmetic mean of those replications;

K is the number of determinations to be made on the actual state.

NOTE The sign + is used when the response variable increases with increasing level of the net state variable and the sign − is used when the response variable decreases with increasing level of the net state variable.

If σ_0 is estimated by s_0, based on ν degrees of freedom, $z_{1-\alpha}$ shall be replaced by the corresponding quantile of Student's t-distribution, i.e.

$$y_c = \bar{y}_b \pm t_{1-\alpha}(\nu)\,s_0\sqrt{\frac{1}{J}+\frac{1}{K}} \quad (3)$$

NOTE The sign + or − is used in the same manner as for Equation (2).

When the value of the state variable in the basic state is known, for all reasonable and foreseeable purposes, to be zero, i.e. the “baseline” for the response variable is known without significant error, then $\sigma_0 = \sigma_b$, the latter being estimated through s_b, the standard deviation of the replicate determinations of the response variable in the basic state. This is the situation addressed in this part of ISO 11843. It is one of several ways in which an experimental estimate of σ_0 can be obtained.

5.2 Practical calculation

The replicated measurements of the response in the basic state should be examined for non-normality of distribution using such techniques as are described in ISO 5479, supplemented by any other available techniques.

For the purposes of this part of ISO 11843, J replicate measurements of the response of the basic state are made, within a measurement series, so that the mean value of y, given by

$$\bar{y}_b = \frac{\sum_{j=1}^{J} y_j}{J}$$

is the estimate of the expectation y_0 of y, and the sample standard deviation of y, given by

$$s_b = \sqrt{\frac{\sum_{j=1}^{J}(y_j - \bar{y}_b)^2}{J-1}}$$

is the estimate of σ_b.

Thus a good estimate of the critical value of the response variable is given by

$$y_c = \bar{y}_b \pm t_{1-\alpha}(\nu) s_b \sqrt{\frac{1}{J} + \frac{1}{K}} \tag{4}$$

where the number of degrees of freedom $\nu = J - 1$. The statistical test is one-sided, α is usually taken as 0,05 as recommended in ISO 11843-1, and the corresponding quantile of Student's t-distribution is obtained from standard tables.

NOTE The sign + or − is used in the same manner as for Equation (2).

Equation (5) applies directly to the situation in which a single determination is made on the test sample:

$$y_c = \bar{y}_b \pm t_{1-\alpha}(\nu) s_b \sqrt{\frac{1}{J} + 1} \tag{5}$$

NOTE The sign + or − is used in the same manner as for Equation (2).

5.3 Reporting and use of the critical value

The number of measurements of the response variable in the basic state J shall be stated together with the standard deviation s_b for that series. The number of replications of the response variable in the actual state K shall also be reported. The chosen value of α shall be stated (usually 0,05). The critical value calculated for the specified number of replications of the response variable in the basic state and actual state shall be stated. These are conveniently set out in tabular form in Table 1.

Table 1 — Critical value of the response variable and its corresponding experimental parameters

Number of replicates of the response variable in the basic state	J
Number of replicates of the response in an actual state	K
Value of α chosen (default value: 0,05)	α
Mean of the response variable in the basic state	$\bar{y}_b$
Mean of the response in the actual state	$\bar{y}_a$
Standard deviation of the response variable in the basic state	s_b
Critical value for the response variable derived by the simplified method of this part of ISO 11843 in which no calibration data are used	y_c

If the average of the K replicate determinations in the actual state is not greater than the critical value, it can be stated that no difference could be shown between the actual state and the basic state. However, the average result for the actual state shall be reported as found. It shall not be reported as zero.

Annex A
(normative)

Symbols used in this part of ISO 11843

b_2	kurtosis test statistic
J	number of replications of measurements of the response variable in the basic state in which the state variable is zero (blank matrix)
$j = 1, 2, \ldots J$	variable identifying the preparations performed on the basic state in which the state variable is zero (blank matrix)
K	number of replications of measurements of the responses of the actual state (sample)
P	probability
s	estimated standard deviation of response variable
s_b	estimated standard deviation of the basic state in which the state variable is zero (blank matrix)
s_0	estimated standard deviation of measured response of the basic state
t	Student's t-distributed test statistic
W	Shapiro-Wilks test statistic
x	a value of the net state variable
y	a value of the response variable
$\bar{y}_b$	arithmetic mean of measured responses from the basic state
$\bar{y}_a$	arithmetic mean of measured responses of an actual state (test sample)
y_c	critical value of the response variable
y_j	jth measurement of the response at a particular level and in a particular series
y_0	expectation of the response variable for zero value of state variable
z	standardized normal random variable with respect to its quantile
α	significance level (i.e. probability of an error of the first kind)
$1 - \alpha$	confidence level
$\nu = J - 1$	degrees of freedom of t-statistic or χ^2-statistic
σ	actual standard deviation
σ_0	actual standard deviation at zero level of state variable
σ_b	actual standard deviation of the response variable for zero value of the state variable (blank matrix or control)
χ^2	chi-squared random variable