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**Measurement uncertainty —
Part 1: Guidance for the use of
repeatability, reproducibility and
trueness estimates in measurement
uncertainty estimation**

ICS 17.020

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Foreword

This translation has been made based on the original Japanese Industrial Standard established by the Minister of Economy, Trade and Industry through deliberations at the Japanese Industrial Standards Committee according to the proposal of establishing a Japanese Industrial Standard from Japanese Standards Association (JSA), with a draft being attached, based on the provision of Article 12 Clause 1 of the Industrial Standardization Law.

This Standard has been made based on **ISO/TS 21748:2004** *Guidance for the use of repeatability, reproducibility and trueness estimates in measurement uncertainty estimation* for the purpose of making it easier to compare this Standard with International Standard; to prepare Japanese Industrial Standard conforming with International Standard; and to propose a draft of an International Standard which is based on Japanese Industrial Standard.

Attention is drawn to the possibility that some parts of this Standard may conflict with a patent right, application for a patent after opening to the public, utility model right or application for registration of utility model after opening to the public which have technical properties. The relevant Minister and the Japanese Industrial Standards Committee are not responsible for identifying the patent right, application for a patent after opening to the public, utility model right or application for registration of utility model after opening to the public which have the said technical properties.

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4-1-24, Akasaka, Minato-ku, Tokyo, 107-8440 JAPAN

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Contents

	Page
Introduction	1
1 Scope	2
2 Normative references	2
3 Terms and definitions	3
4 Symbols	6
5 Principles	9
5.1 Individual results and measurement process performance	9
5.2 Applicability of reproducibility data	9
5.3 Basic equations for the statistical model	9
5.4 Repeatability data	11
6 Evaluating uncertainty using repeatability, reproducibility and trueness estimates	11
6.1 Procedure for evaluating measurement uncertainty	11
6.2 Differences between expected and actual precision	11
7 Establishing the relevance of method performance data to measurement results from a particular measurement process	11
7.1 General	11
7.2 Demonstrating control of the laboratory component of bias	12
7.3 Verification of repeatability	14
7.4 Continued verification of performance	15
8 Establishing relevance to the test item	15
8.1 General	15
8.2 Sampling	15
8.3 Sample preparation and pre-treatment	16
8.4 Changes in test-item type	16
8.5 Variation of uncertainty with level of response	16

9	Additional factors	17
10	General expression for combined standard uncertainty	17
11	Uncertainty budgets based on collaborative study data	18
12	Evaluation of uncertainty for a combined result	19
13	Expression of uncertainty information	20
13.1	General expression	20
13.2	Choice of coverage factor	20
14	Comparison of method performance figures and uncertainty data	21
14.1	Basic assumptions for comparison	21
14.2	Comparison procedure	21
14.3	Reasons for differences	22
	Annex A (informative) Approaches to uncertainty estimation	23
	Annex B (informative) Experimental uncertainty evaluation	28
	Annex C (informative) Examples of uncertainty calculations	30
	Bibliography	35

Measurement uncertainty—Part 1: Guidance for the use of repeatability, reproducibility and trueness estimates in measurement uncertainty estimation

Introduction This Japanese Industrial Standard has been prepared based on the first edition of **ISO/TS 21748** *Guidance for the use of repeatability, reproducibility and trueness estimates in measurement uncertainty estimation* published in 2004 without modifying the technical contents.

The portions underlined with dots are the matters not stated in the original International Standard.

Knowledge of the uncertainty associated with measurement results is essential to the interpretation of the results. Without quantitative assessments of uncertainty, it is impossible to decide whether observed differences between results reflect more than experimental variability, whether test items comply with specifications, or whether laws based on limits have been broken. Without information on uncertainty, there is a risk of misinterpretation of results. Incorrect decisions taken on such a basis may result in unnecessary expenditure in industry, incorrect prosecution in law, or adverse health or social consequences.

Laboratories operating under **JIS Q 17025** accreditation and related systems are accordingly required to evaluate measurement uncertainty for measurement and test results and report the uncertainty where relevant. The Guide to the expression of uncertainty in measurement (GUM), published by **ISO**, is a widely adopted standard approach. However, it applies to situations where a model of the measurement process is available. A very wide range of standard test methods is, however, subjected to collaborative study in accordance with **JIS Z 8402-2**. This Standard provides an appropriate and economic methodology for estimating uncertainty associated with the results of these methods, which complies fully with the relevant principles of the GUM, whilst taking account of method performance data obtained by collaborative study.

The general approach used in this Standard requires that

- estimates of the repeatability, reproducibility and trueness of the method in use, obtained by collaborative study as described in **JIS Z 8402-2**, be available from published information about the test method in use. These provide estimates of the intra- and inter-laboratory components of variance, together with an estimate of uncertainty associated with the trueness of the method;
- the laboratory confirm that its implementation of the test method is consistent with the established performance of the test method by checking its own bias and precision. This confirms that the published data are applicable to the results obtained by the laboratory;
- any influences on the measurement results that were not adequately covered by the collaborative study be identified and the variance associated with the results that could arise from these effects be quantified.

An uncertainty estimate is made by combining the relevant variance estimates in the manner prescribed by the GUM.

The dispersion of results obtained in a collaborative study is often also usefully compared with measurement uncertainty estimates obtained using GUM procedures as a test of full understanding of the method. Such comparisons will be more effective given a consistent methodology for estimating the same parameter using collaborative study data.

1 Scope This part of **JIS Z 8404** gives guidance for

- evaluation of measurement uncertainties using data obtained from studies conducted in accordance with **JIS Z 8402-2**;
- comparison of collaborative study results with measurement uncertainty (MU) obtained using formal principles of uncertainty propagation (see clause **14**).

JIS Z 8402-3 provides additional models for studies of intermediate precision. However, while the same general approach may be applied to the use of such extended models, uncertainty evaluation using these models is not incorporated in the present Standard.

This part of **JIS Z 8404** is applicable in all measurement and test fields where an uncertainty associated with a result has to be determined.

This part of **JIS Z 8404** does not describe the application of repeatability data in the absence of reproducibility data.

This part of **JIS Z 8404** assumes that recognized, non-negligible systematic effects are corrected, either by applying a numerical correction as part of the method of measurement, or by investigation and removal of the cause of the effect.

The recommendations in this part of **JIS Z 8404** are primarily for guidance. It is recognized that while the recommendations presented do form a valid approach to the evaluation of uncertainty for many purposes, it is also possible to adopt other suitable approaches.

In general, references to measurement results, methods and processes in this part of **JIS Z 8404** are normally understood to apply also to testing results, methods and processes.

NOTE : The International Standard corresponding to this part of **JIS Z 8404** as follows.

In addition, symbols which denote the degree of correspondence in the contents between the relevant International Standard and **JIS** are IDT (identical), MOD (modified), and NEQ (not equivalent) according to **ISO/IEC Guide 21**.

ISO/TS 21748:2004 *Guidance for the use of repeatability, reproducibility and trueness estimates in measurement uncertainty estimation* (IDT)

2 Normative references The following standards contain provisions which, through reference in this text, constitute provisions of this Standard. The most recent editions of the standards (including amendments) indicated below shall be applied.

JIS Q 0033 Uses of certified reference materials

NOTE : **ISO Guide 33** *Uses of certified reference materials* is identical with the said standard.

Information : Although this Standard is listed in Bibliography of the original International Standard, it is referred as one of the provision items in the text, so it is added in Normative references.

JIS Z 8101-1 Statistics—Vocabulary and symbols—Part 1: Probability and general statistical terms

NOTE : **ISO 3534-1** *Statistics—Vocabulary and symbols—Part 1: Probability and general statistical terms* is equivalent to the said standard.

JIS Z 8101-2 Statistics—Vocabulary and symbols Part 2: Statistical quality control terms

NOTE : **ISO 3534-2** *Statistics—Vocabulary and symbols—Part 2: Statistical quality control* is equivalent to the said standard.

JIS Z 8402-2 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

NOTE : **ISO 5725-2** *Accuracy (trueness and precision) of measurement methods and results—Part 2: Basic method for the determination of the repeatability and reproducibility of a standard measurement method* is identical with the said standard.

JIS Z 8402-3 Accuracy (trueness and precision) of measurement methods and results—Part 3: Intermediate measures of the precision of a standard measurement method

NOTE : **ISO 5725-3** *Accuracy (trueness and precision) of measurement methods and results—Part 3: Intermediate measures of the precision of a standard measurement method* is identical with the said standard.

3 Terms and definitions For the purposes of this Standard, the following terms and definitions apply. In addition, reference is made to “intermediate precision conditions”, which are discussed in detail in **JIS Z 8402-3**.

3.1 bias value obtained by subtracting the true value from the expectation of the observed value or the test result

NOTE : An accepted reference value or a conventional true value is actually used in substitution for the true value (see **JIS Z 8101-1**).

Information : The term is defined as “difference between the expectation of the test results and an accepted reference value” in the original International Standard.

3.2 combined standard uncertainty $u(y)$ standard uncertainty of the result of a measurement when that result is obtained from the values of a number of other quantities, equal to the positive square root of a sum of terms, the terms being the

variances or covariances of these other quantities weighted according to how the measurement result varies with changes in these quantities (see GUM)

3.3 coverage factor k numerical factor used as a multiplier of the combined standard uncertainty in order to obtain an expanded uncertainty

NOTE : A coverage factor, k , is typically in the range 2 to 3 (see GUM).

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

NOTES 1 The fraction may be regarded as the coverage probability or level of confidence of the interval.

2 To associate a specific level of confidence with the interval defined by the expanded uncertainty requires explicit or implicit assumptions regarding the probability distribution characterised 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 can be justified.

3 Expanded uncertainty is termed overall uncertainty in Recommendation INC-1 (1980), paragraph 5 (see GUM).

3.5 precision a degree of the dispersion of independent observed value and test result obtained from the same sample under a specified condition

It is said that the smaller dispersion, the better or higher the precision is.

NOTES 1 Precision depends upon the distribution of random errors and does not relate to the true value or the specified value.

2 Independent observed values means values obtained in a manner not influenced by any observed values on the same or similar test object. The same applies to independent test results. Quantitative measures of precision depend on the repeatability conditions. Repeatability and reproducibility conditions are examples of repeatability conditions (see **JIS Z 8101-2**).

Information 1 The term is defined as “closeness of agreement between independent test results obtained under stipulated conditions” in the original International Standard.

Information 2 The description of NOTE 2 is not clear, so the complementary explanation is added.

“Independent test results” means results obtained in a manner not influenced by any previous result on the same or similar test object. Quantitative measures of precision depend critically on the stipulated conditions. Repeatability and reproducibility conditions are particular examples of extreme stipulated conditions.

3.6 repeatability precision of the observed values and the test results under the repeatability conditions

When expressed with standard deviation, it is called repeatability standard deviation and when expressed with variance, it is called repeatability variance.

Information : The term is defined as “precision under repeatability conditions, i.e. conditions where independent test results are obtained with the same method on identical test items in the same laboratory by the same operator using the same equipment within short intervals of time” in the original International Standard.

3.7 repeatability standard deviation standard deviation of test results obtained under repeatability conditions

NOTE : This is a measure of dispersion of the distribution of test results under repeatability conditions. Similarly “repeatability variance” and “repeatability coefficient of variation” can be defined and used as measures of the dispersion of test results under repeatability conditions (see **JIS Z 8101-2**).

3.8 reproducibility precision of the test results under the reproducibility conditions

When expressed with standard deviation, it is called reproducibility standard deviation and when expressed with variance, it is called reproducibility variance.

Information : The term is defined as “precision under reproducibility conditions, i.e. conditions where test results are obtained with the same method on identical test items in different laboratories with different operators using different equipment” in the original International Standard.

3.9 reproducibility standard deviation standard deviation of test results obtained under reproducibility conditions

NOTE : This is a measure of dispersion of the distribution of test results under reproducibility conditions. Similarly “reproducibility variance” and “reproducibility coefficient of variation” could be defined and used as measures of the dispersion of test results under reproducibility conditions (see **JIS Z 8101-2**).

3.10 standard uncertainty $u(x_i)$ uncertainty of the result of a measurement expressed as a standard deviation (see GUM)

3.11 trueness degree of bias from the true value

It is said that the smaller bias, the better or higher the trueness is.

NOTE : The reference value or the conventional true value is actually used in substitution for the true value (see **JIS Z 8101-2**).

Information : The term is defined as “closeness of agreement between the average value obtained from a large set of test results and an accepted reference value” in the original International Standard.

3.12 uncertainty 〈measurement〉 parameter, associated with the result of a measurement, that characterizes the dispersion of the values that could reasonably be attributed to the measurand

- NOTES 1 The parameter may be, for example, a standard deviation (or a given multiple of it), or the half-width of an interval having a stated level of confidence.
- 2 Uncertainty of measurement comprises, in general, many components. Some of these components may be evaluated from the statistical distribution of the results of a series of measurements and can be characterized by experimental standard deviations. Other components, which also can be characterized by standard deviations, are evaluated from assumed probability distributions based on experience or other information.
- 3 It is understood that the result of the measurement is the best estimate of the value of the measurand, and that all components of uncertainty, including those arising from systematic effects such as components associated with corrections and reference standards, contribute to the dispersion (see GUM).

3.13 uncertainty budget list of sources of uncertainty and their associated standard uncertainties, compiled with a view to evaluating a combined standard uncertainty associated with a measurement result

NOTE : The list often includes additional information such as sensitivity coefficients (rate of change of result with change in a quantity affecting the result), degrees of freedom for each standard uncertainty, and an identification of the means of evaluating each standard uncertainty in terms of a Type A or Type B evaluation.

4 Symbols

a	coefficient indicating an intercept in the empirical relationship $\hat{s}_R = a + bm$
B	laboratory component of bias
b	coefficient indicating a slope in the empirical relationship $\hat{s}_R = a + bm$
c	coefficient in the empirical relationship $\hat{s}_R = cm^d$
c_i	sensitivity coefficient $\partial y / \partial x_i$
d	coefficient indicating an exponent in the empirical relationship $\hat{s}_R = cm^d$
e	random residual error
e_r	random residual error under repeatability conditions
k	numerical factor used as a multiplier of the combined standard uncertainty u in order to obtain an expanded uncertainty U
l	laboratory number
m	mean value of the measurements
N	number of contributions included in combined uncertainty calculations

n'	number of contributions incorporated in combined uncertainty calculations in addition to collaborative study data
n_l	number of replicates at one level by laboratory l
n_r	number of replicate measurements
p	number of laboratories
Q	number of test items from a larger batch
q	number of assigned values by consensus during a collaborative study
r_{ij}	correlation coefficient between x_i and x_j , in the range -1 to $+1$
s_b	between-group component of variance expressed as a standard deviation
s_b^2	between-group component of variance
s_D	estimated, or experimental, standard deviation of results obtained by repeated measurement on a reference material used for checking control of bias
	<u>Information : This standard deviation corresponds to the positive square root of the mean of squared deviations from the certified value.</u>
s_i	repeatability standard deviation with ν_i degrees of freedom
s_{inh}	uncertainty associated with the inhomogeneity of the sample
s_{inh}^2	component of variance associated with the inhomogeneity of the sample
s_L	experimental or estimated inter-laboratory standard deviation
$\hat{s}_L$	adjusted standard deviation associated with B where the contribution is dependent on the response
	<u>Information : "Uncertainty" is adopted in the original International Standard instead of "standard deviation".</u>
s_L^2	the estimated variance of B
s_r	intra-laboratory standard deviation
$\hat{s}_r$	adjusted estimate of inter-laboratory standard deviation, where the contribution is dependent on the response
s_r^2	estimated variance of e_r
s_R	estimated reproducibility standard deviation
s'_R	adjusted estimate of the reproducibility standard deviation
$\hat{s}_R$	adjusted reproducibility standard deviation calculated from an empirical model, where the contributions are dependent on the response
s_w	intra-laboratory standard deviation derived from replicates or other repeatability studies
s_w^2	intra-group component of variance (often an intra-laboratory component of variance)
$s(\Delta_y)$	laboratory standard deviation of differences during a comparison of a routine method with a definitive method

x_i	value of the i th input value in the determination of a result
x'_i	deviation of the i th input value from the nominal value of x
x_j	the j th input value in the determination of a result
$u(\hat{\delta})$	uncertainty associated with δ due to the uncertainty of estimating δ by measuring a reference measurement standard or reference material with certified value $\hat{\mu}$
$u(\hat{\mu})$	uncertainty associated with the certified value $\hat{\mu}$
$u(y)$	combined standard uncertainty associated with y where $u(y) = \sqrt{\sum_{i=1,n} c_i^2 u^2(x_i)}$
$u(Y)$	combined standard uncertainty for the result $Y = f(y_1, y_2, \dots)$ where $u(Y) = \sqrt{\sum_i [c_i u(y_i)]^2}$
$u^2(y)$	combined standard uncertainty associated with y , expressed as a variance
u_{inh}	uncertainty associated with sample inhomogeneity
U	expanded uncertainty, equal to k times the standard uncertainty u
$U(y)$	expanded uncertainty in y where $U(y) = k u(y)$, where k is a coverage factor
y_i	result for test item i from the definitive method during a comparison of methods
$\hat{y}_i$	result for test item i from the routine test method during a comparison of methods
y_0	assigned value for proficiency testing
Δ	laboratory bias
Δ_l	estimate of bias of laboratory l , equal to the laboratory mean, m , minus the certified value, $\hat{\mu}$
$\bar{\Delta}_y$	mean laboratory bias during a comparison of a routine method with a definitive method
δ	bias intrinsic to the measurement method in use
$\hat{\delta}$	estimated or measured bias
μ	unknown expectation of the ideal result (true value)
$\hat{\mu}$	certified value of a reference material
σ_0	standard deviation for proficiency testing
σ_D	true value of the standard deviation of results obtained by repeated measurement on a reference material used for checking control of bias
Information : This standard deviation corresponds to the positive square root of the expectation of squared deviations from the certified value.	
σ_L	inter-laboratory standard deviation; standard deviation of B
σ_L^2	variance of B ; inter-laboratory variance
σ_r	intra-laboratory standard deviation; standard deviation of e_r
σ_r^2	variance of e_r ; intra-laboratory variance

σ_w	within-group standard deviation
σ_{w0}	standard deviation required for adequate performance (see JIS Q 0033)
ν_{eff}	effective degrees of freedom for the standard deviation of, or uncertainty associated with input value x_i
ν_i	number of degrees of freedom

5 Principles

5.1 Individual results and measurement process performance

5.1.1 Measurement uncertainty relates to individual results. Repeatability, reproducibility, and bias, by contrast, relate to the performance of a measurement or testing process. For studies under all parts of **JIS Z 8402**, the measurement or testing process will be a single measurement method, used by all laboratories taking part in the study. Note that for the purposes of this Standard, the measurement method is assumed to be implemented in the form of a single detailed procedure (as defined in the International Vocabulary of Basic and General Terms in Metrology). It is implicit in this Standard that process-performance figures derived from method-performance studies are relevant to all individual measurement results produced by the process. It will be seen that this assumption requires supporting evidence in the form of appropriate quality control and assurance data for the measurement process (clause 7).

5.1.2 It will be seen below that differences between individual test items may additionally need to be taken into account, but, with that caveat, it is unnecessary to undertake individual and detailed uncertainty studies for every test item for a well characterized and stable measurement process.

5.2 Applicability of reproducibility data The application of the principles of this Standard is based on two principles.

- First, the reproducibility standard deviation obtained in a collaborative study is a valid basis for measurement uncertainty evaluation (see **A.2.1** of Annex A).
- Second, effects not observed within the context of the collaborative study must be demonstrably negligible or explicitly allowed for. The latter principle is implemented by an extension of the basic model used for collaborative study (see **A.2.3** of Annex A).

5.3 Basic equations for the statistical model

5.3.1 The statistical model on which this guidance is based is formulated as in Equation (1):

$$y = \mu + \delta + B + \sum c_i x'_i + e \dots\dots\dots (1)$$

where,

- y is an observed result, assumed to be calculated from the equation: $y = f(x_1, x_2, \dots, x_n)$;
- μ is the (unknown) expectation of ideal results;