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# Measurement uncertainty for metrological applications — Repeated measurements and nested experiments

*Incertitude de mesure pour les applications en métrologie — Mesures répétées et expériences emboîtées*

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# Foreword

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ISO/TS 21749 was prepared by Technical Committee ISO/TC 69, *Applications of statistical methods*, Subcommittee SC 6, *Measurement methods and results*.

This corrected version of ISO/TS 21749:2005 incorporates the correction of the title.

# Introduction

Test, calibration and other laboratories are frequently required to report the results of measurements and the associated uncertainties. Evaluation of uncertainty is an on-going process that can consume time and resources. In particular, there are many tests and other operations carried out by laboratories where two or three sources of uncertainty are involved. Following the approach in the *Guide to the expression of uncertainty of measurement* (*GUM*) to combining components of uncertainty, this document focuses on using the analysis of variance (ANOVA) for estimating individual components, particularly those based on Type A (statistical) evaluations.

An experiment is designed by the laboratory to enable an adequate number of measurements to be made, the analysis of which will permit the separation of the uncertainty components. The experiment, in terms of design and execution, and the subsequent analysis and uncertainty evaluation, require familiarity with data analysis techniques, particularly statistical analysis. Therefore, it is important for laboratory personnel to be aware of the resources required and to plan the necessary data collection and analysis.

In this Technical Specification, the uncertainty components based on Type A evaluations can be estimated from statistical analysis of repeated measurements, from instruments, test items or check standards.

A purpose of this Technical Specification is to provide guidance on the evaluation of the uncertainties associated with the measurement of test items, for instance as part of ongoing manufacturing inspection. Such uncertainties contain contributions from the measurement process itself and from the variability of the manufacturing process. Both types of contribution include those from operators, environmental conditions and other effects. In order to assist in separating the effects of the measurement process and manufacturing variability, measurements of check standards are used to provide data on the measurement process itself. Such measurements are nominally identical to those made on the test items. In particular, measurements on check standards are used to help identify time-dependent effects, so that such effects can be evaluated and contrasted with a database of check standard measurements. These standards are also useful in helping to control the bias and long-term drift of the process once a baseline for these quantities has been established from historical data.

Clause 4 briefly describes the statistical methods of uncertainty evaluation including the approach recommended in the *GUM*, the use of check standards, the steps in uncertainty evaluation and the examples in this Technical Specification. Clause 5, the main part of this Technical Specification, discusses the Type A evaluations. Nested designs in ANOVA are used in dealing with time-dependent sources of uncertainty. Other sources such as those from the measurement configuration, material inhomogeneity, and the bias due to measurement configurations and related uncertainty analyses are discussed. Type B (non-statistical) evaluations of uncertainty are discussed for completeness in Clause 6. The law of propagation of uncertainty described in the *GUM* has been widely used. Clause 7 provides formulae obtained by applying this law to certain functions of one and two variables. In Clause 8, as an example, a Type A evaluation of uncertainty for a gauge study is discussed, where uncertainty components from various sources are obtained. Annex A lists the statistical symbols used in this Technical Specification.