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**Measurement of fluid flow — Evaluation of  
uncertainties**

*Mesure de débit des fluides — Calcul de l'incertitude*



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International Organization for Standardization  
Case postale 56 • CH-1211 Genève 20 • Switzerland  
Internet central@iso.ch  
X.400 c=ch; a=400net; p=iso; o=isocs; s=central

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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 main task of technical committees is to prepare International Standards, but in exceptional circumstances a technical committee may propose the publication of a Technical Report of one of the following types:

- type 1, when the required support cannot be obtained for the publication of an International Standard, despite repeated efforts;
- type 2, when the subject is still under technical development or where for any other reason there is the future but not immediate possibility of an agreement on an International Standard;
- type 3, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example).

Technical Reports of types 1 and 2 are subject to review within three years of publication, to decide whether they can be transformed into International Standards. Technical Reports of type 3 do not necessarily have to be reviewed until the data they provide are considered to be no longer valid or useful.

ISO/TR 5168, which is a Technical Report of type 1, was prepared by Technical Committee ISO/TC 30, *Measurement of fluid flow in closed conduits*, Subcommittee SC 9, *Uncertainties in flow measurement*.

This document is being issued as a type 1 Technical Report because no consensus could be reached between ISO TC 30/SC 9 and ISO/TAG 4, *Metrology*, concerning the harmonization of this document with the *Guide to the expression of uncertainty in measurement*, which is a basic document in the ISO/IEC Directives. A future revision of this Technical Report will align it with the *Guide*.

This first edition as a Technical Report cancels and replaces the first edition as an International Standard (ISO 5168:1978), which has been technically revised.

Annexes A and B form an integral part of this Technical Report.  
Annexes C, D, E and F are for information only.

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## Introduction

One of the first International Standards to specifically address the subject of uncertainty in measurement was ISO 5168, *Measurement of fluid flow — Estimation of uncertainty of a flow-rate measurement*, published in 1978. The extensive use of ISO 5168 in practical applications identified many improvements to its methods; these were incorporated into a draft revision of this International Standard, which in 1990 received an overwhelming vote in favour of its publication. However, this draft revision of ISO 5168 was withheld from publication for a number of years since, despite lengthy discussions, no consensus could be reached with the draft version of a document under development by a Working Group of ISO Technical Advisory Group 4, *Metrology* (ISO TAG 4/WG 3). The TAG 4 document, *Guide to the expression of uncertainty in measurement* (GUM), was published in late 1993 as a basic document in the ISO/IEC Directives. At a meeting of the ISO Management Board in May 1995 it was decided to publish the revision of ISO 5168, *Measurement of fluid flow — Evaluation of uncertainties*, as a Technical Report.

One of the major differences between ISO/TR 5168 and the GUM is in the definitions and terminology. In addition, a substantial difference exists with respect to the concepts to be used to define practical measurement processes. In this Technical Report a normal distribution of the measurement data is assumed and Student's  $t$ -factor is used to determine the uncertainty. The method used to propagate elemental uncertainties to the overall uncertainty is essentially identical to that used in the GUM.

This document is published as a type 1 Technical Report instead of an International Standard because it is not consistent with the GUM. A future revision of this Technical Report will align the two documents.



# Measurement of fluid flow — Evaluation of uncertainties

## 1 Scope

Whenever a measurement of flowrate (discharge) is made, the value obtained from the experimental data is simply the best possible estimate of the true flowrate. In practice, the true flowrate may be slightly greater or less than this value.

**1.1** This Technical Report details step-by-step procedures for the evaluation of uncertainties in individual flow measurements arising from both random and systematic error sources and for the propagation of component uncertainties into the uncertainty of the test results. These procedures enable the following processes to be carried out:

- a) estimation of the accuracy of results derived from flowrate measurement;
- b) selection of a proper measuring method and devices to achieve a required level of accuracy of flowrate measurement;
- c) comparison of the results of measurement;
- d) identification of the sources of errors contributing to a total uncertainty;
- e) refinement of the results of measurement as data accumulate.

NOTE — It is assumed that the measurement process is carefully controlled and that all calibration corrections have been applied.

**1.2** This Technical Report describes the calculations required in order to arrive at an estimate of the interval within which the true value of the flowrate may be expected to lie. The principle of these calculations is applicable to any flow measurement method, whether the flow is in an open channel or in a closed conduit.

NOTE — Although this Technical Report has been drafted taking mainly into account the sources of error due to the instrumentation, it should be emphasized that the errors due to the flow itself (velocity distribution, turbulence, etc.) and to its effect on the method and on the response of the instrument can be of great importance with certain methods of flow measurement (see 5.7). Where a particular device or technique is used, some simplifications may be possible or special reference may have to be made to specific sources of error not identified in this Technical Report. Therefore reference should be made to the "Uncertainty of measurement" clause of the appropriate International Standard dealing with that device or technique.

## 2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this Technical Report. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this Technical Report are encouraged to investigate the possibility of applying

the most recent editions of the standards listed below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 5725-1:1994, *Accuracy (trueness and precision) of measurement methods and results — Part 1: General principles and definitions.*

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 5725-3:1994, *Accuracy (trueness and precision) of measurement methods and results — Part 3: Intermediate measures of the precision of a standard measurement method.*

ISO 5725-4:1994, *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 5725-6:1994, *Accuracy (trueness and precision) of measurement methods and results — Part 6: Use in practice of accuracy values.*

### 3 Definitions and symbols

For the purposes of this Technical Report, the following definitions and symbols apply.

#### 3.1 Definitions

**3.1.1 correction:** Value which must be added algebraically to the indicated value to obtain the corrected result. It is numerically the same as a known error, but of opposite sign.

**3.1.2 coverage:** Percentage frequency at which an interval estimate of a parameter contains the true value. That is, in repeated sampling when the uncertainty interval provides 95 % coverage for each sample, over the long run the intervals will contain the true value 95 % of the time.

**3.1.3 error:** Result of a measurement minus the (conventional) true value of the measurement. See figure 1.

NOTE — The known parts of an error of measurement may be compensated by applying appropriate corrections. The error of the corrected result can be characterized by an uncertainty.

**3.1.4 estimate:** Value calculated from a sample of data as a substitute for an unknown population parameter.

For example, the experimental standard deviation ( $s$ ) is the estimate which describes the population standard deviation ( $\sigma$ ).

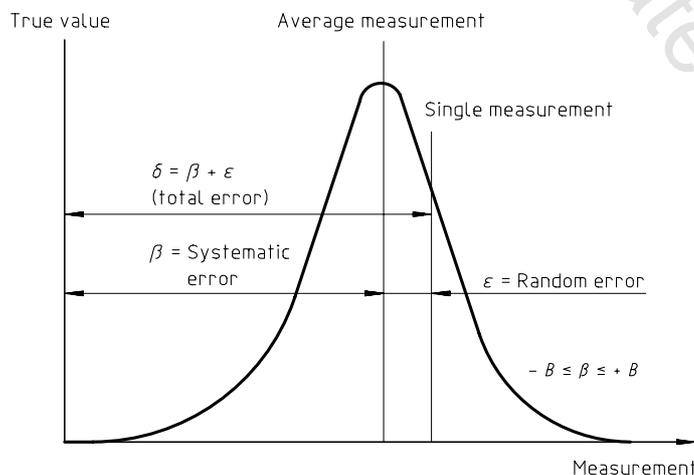


Figure 1 — Measurement error