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Measurement of fluid flow — Procedures for the evaluation of uncertainties

Mesure de débit des fluides — Procédures pour le calcul de l'incertitude

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Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

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.

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.

ISO 5168 was prepared by Technical Committee ISO/TC 30, *Measurement of fluid flow in closed conduits*, Subcommittee SC 9, *General topics*.

This second edition of ISO 5168 cancels and replaces ISO/TR 5168:1998, which has been technically revised (see Annex I).

Introduction

Whenever a measurement of fluid flow (discharge) is made, the value obtained is simply the best estimate that can be obtained of the flow-rate or quantity. In practice, the flow-rate or quantity could be slightly greater or less than this value, the uncertainty characterizing the range of values within which the flow-rate or quantity is expected to lie, with a specified confidence level.

GUM is the authoritative document on all aspects of terminology and evaluation of uncertainty and should be referred to in any situation where this International Standard does not provide enough depth or detail. In particular, GUM (1995), Annex F, gives guidance on evaluating uncertainty components.

Measurement of fluid flow — Procedures for the evaluation of uncertainties

1 Scope

This International Standard establishes general principles and describes procedures for evaluating the uncertainty of a fluid flow-rate or quantity.

A step-by-step procedure for calculating uncertainty is given in Annex A.

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 9300, *Measurement of gas flow by means of critical flow Venturi nozzles*

ISO Guide to the expression of uncertainty in measurement (*GUM*), 1995

International vocabulary of basic and general terms in metrology (*VIM*), 1993

3 Terms and definitions

For the purposes of this document, the terms and definitions given in VIM (1993), GUM (1995) and the following apply.

3.1
uncertainty
parameter, associated with the results of a measurement, that characterizes the dispersion of the values that could reasonably be attributed to the measurand

NOTE Uncertainties are expressed as an absolute value and do not take a positive or negative sign.

3.2
standard uncertainty
$u(x)$
uncertainty of the result of a measurement expressed as a standard deviation

3.3
relative uncertainty
$u^*(x)$
standard uncertainty divided by the best estimate

NOTE 1 $u^*(x) = u(x)/x$.

NOTE 2 $u^*(x)$ can be expressed either as a percentage or in parts per million.

NOTE 3 Relative uncertainty is sometimes referred to as dimensionless uncertainty.

NOTE 4 The best estimate is in most cases the arithmetic mean of the related uncertainty interval.

3.4
combined standard uncertainty
$u_c(y)$
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

3.5
relative combined uncertainty
$u_c^*(y)$
combined standard uncertainty divided by the best estimate

NOTE 1 $u_c^*(y)$ can be expressed as a percentage or parts per million.

NOTE 2 $u_c^*(y) = u_c(y)/y$.

NOTE 3 Relative combined uncertainty is sometimes referred to as dimensionless combined uncertainty.

NOTE 4 The best estimate is in most cases the arithmetic mean of the related uncertainty interval.

3.6
expanded uncertainty
U
quantity defining an interval about the result of a measurement that can be expected to encompass a large fraction of the distribution of values that could reasonably be attributed to the measurand

NOTE 1 The fraction can be viewed as the coverage probability or the confidence level of the interval.

NOTE 2 $U = ku_c(y)$

3.7
relative expanded uncertainty
U^*
expanded uncertainty divided by the best estimate

NOTE 1 U^* can be expressed as a percentage or in parts per million.

NOTE 2 $U^* = ku_c^*(y)$.

NOTE 3 Relative expanded uncertainty is sometimes referred to as dimensionless expanded uncertainty.

NOTE 4 The best estimate is in most cases the arithmetic mean of the related uncertainty interval.

3.8
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 is typically in the range 2 to 3.

3.9
Type A evaluation
⟨uncertainty⟩ method of evaluation of uncertainty by the statistical analysis of a series of observations

3.10
Type B evaluation
⟨uncertainty⟩ method of evaluation of uncertainty by means other than the statistical analysis of a series of observations

3.11
sensitivity coefficient
c_i
change in the output estimate, y, divided by the corresponding change in the input estimate, x_i

3.12
relative sensitivity coefficient
c^*_i
relative change in the output estimate, y, divided by the corresponding relative change in the input estimate, x_i

4 Symbols and abbreviated terms

4.1 Symbols

a_i	estimated semi-range of a component of uncertainty associated with input estimate, x_i, as defined in Annex B
A_t	area of the throat
b_i	breadth associated with a vertical i
b'_i	upper bound of an asymmetric uncertainty distribution as defined in Annex B
c_i	sensitivity coefficient used to multiply the uncertainty in the input estimate, x_i, to obtain the effect of a change in the input quantity on the uncertainty of the output estimate, y
c^*_i	relative sensitivity coefficient used to multiply the relative uncertainty in input estimate, x_i, to obtain the effect of a relative change in the input quantity on the relative uncertainty of the output estimate, y
C_c	calibration coefficient
C	discharge coefficient
C_V	coefficient of variation
d_i	depth associated with a vertical i
d_o	orifice diameter
$d_{\mathrm{o},0}$	orifice diameter measured at temperature $T_{0,x}$
d_p	pipe diameter
$d_{\mathrm{p},0}$	pipe diameter measured at temperature $T_{0,x}$
$\overline{E}$	mean meter error, expressed as a fraction

E_j — jth meter error, expressed as a fraction

f — functional relationship between estimates of the measurand, y, and the input estimates, x_i, on which y depends

$\frac{\partial f}{\partial x_i}$ — partial derivative with respect to input quantity, x_i, of the functional relationship, f, between the measurand and the input quantities

F — flow factor, equal to $\frac{q}{\sqrt{\Delta p_\mathrm{r}}}$

F_exp — flow factor for a new design

F_Redp — $\left(19\,000 \cdot \beta / \mathrm{Re}_\mathrm{dp}\right)^{0,8}$

F_ref — reference flow factor

F_s — factor, assumed to be unity, that relates the discrete sum over the finite number of verticals to the integral of the continuous function over the cross-section

k — coverage factor used to calculate the expanded uncertainty, U

k_t — coverage factor derived from a table; see D.12

K — meter factor

$\overline{K}$ — mean meter factor

K_j — jth K-factor;

l_b — length of crest

l_h — gauged head

l_1 — distance from the upstream tapping to the upstream face

L_1 — l_1 divided by the pipe diameter, d_p

l'_2 — distance from the downstream tapping to the downstream face

L'_2 — l'_2 divided by the pipe diameter, d_p

m — particular item in a set of data

m' — number of data sets to be pooled

m'' — number of verticals

M'_2 — $2L'_2/(1-\beta)$

n — number of repeat readings or observations

n' — exponent of l_h, usually 1,5 for a rectangular weir and 2,5 for a V-notch

n''	number of depths in a vertical at which velocity measurements are made
N	number of input estimates, x_i, on which the measurand depends
p_0	upstream pressure
Δp_{mt}	pressure difference across the orifice meter
Δp_{r}	pressure difference across the radiator
$P(a_i)$	probability that an input estimate, x_i, has a value of a_i
q	volume flow-rate
q_{ma}	mass flow;
Q	flow, expressed in cubic metres per second, at flowing conditions
R	specific gas constant
$\mathrm{Re}_{\mathrm{dp}}$	Reynolds number related to d_{p} by the expression $Vd_{\mathrm{p}}\rho/\mu$
$s_{\mathrm{mt,po}}$	pooled experimental standard deviation of the orifice plate readings
s_{pe}	standard deviation of a larger set of data used with a smaller data set
s_{po}	standard deviation pooled from several sets of data
$s_{\mathrm{r,po}}$	pooled experimental standard deviation for the radiator readings
$s(x)$	experimental standard deviation of a random variable, x, determined from n repeated observations
$s(\bar{x})$	experimental standard deviation of the arithmetic mean, $\bar{x}$
t	Student's statistic
T_0	upstream absolute temperature
$T_{0,x}$	temperature at which measurement x is made
T_{op}	operating temperature
$u_{\mathrm{c,corr}}(y)$	combined uncertainty for those components for multiple meters that are correlated
$u_{\mathrm{c,uncorr}}(y)$	combined uncertainty for those components for multiple meters that are uncorrelated
u^*_{cal}	instrument calibration uncertainty from all sources, formerly called systematic errors or biases
$u^*_{\mathrm{cr}i}$	relative uncertainty in point velocity at a particular depth in vertical i due to the variable responsiveness of the current meter
u^*_{d}	relative standard uncertainty in the coefficient of discharge