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DRAFT UGANDA STANDARD

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Measurement of fluid flow — Methods of specifying flowmeter performance

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Foreword

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Draft Uganda Standards adopted by the Technical Committee are widely circulated to stakeholders and the general public for comments. The committee reviews the comments before recommending the draft standards for approval and declaration as Uganda Standards by the National Standards Council.

The committee responsible for this document is Technical Committee UNBS/TC 16, *Petroleum*, Subcommittee SC 2, *Drilling, Development and production equipment and materials*.

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Measurement of fluid flow — Methods of specifying flowmeter performance

1 Scope

This Draft Uganda Standard specifies methods of describing the performance of any flowmeter, for use in either closed conduits or open channels. It indicates how flowmeters may be classified according to their traceability group, and specifies how manufacturer's statements on traceability, quality assurance and conditions of use should be expressed, although further statements may be required for other conditions of use.

2 Normative references

The following referenced documents referred to in the text in such a way that some or all of their content constitutes requirements 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.

DUS ISO 5168, *Measurement of fluid flow — Estimation of uncertainty of a flowrate measurement*.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply. :

3.1
accuracy (deprecated)
ability of a flowmeter to give responses close to a true value

3.2
calibration
set of operations which establish, under specified conditions, the relationship between values of quantities indicated by a flowmeter and the corresponding values indicated by a standard of reference

NOTE 1 The result of a calibration permits either the assignment of values of measurands to the indications or the determination of corrections with respect to indications.

NOTE 2 A calibration may also determine other metrological properties, such as the effect of influence quantities.

NOTE 3 The result of a calibration may be recorded in a document, sometimes called a calibration certificate or a calibration report.

NOTE 4 The result of a calibration is often expressed as a calibration factor, or as a series of calibration factors, or as a calibration curve.

NOTE 5 Calibration does not include adjustment.

3.3
linearity
specific, but often used, case of conformity in which the specified curve is a straight line

NOTE Illustrations of linearity are given in annex A.

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3.4
deadband
maximum interval through which a stimulus can be changed in both directions without producing a change in response of the flowmeter

NOTE Some flowmeters (turbines for example) may have a “deadband” from zero flow to some flowrate but thereafter have a small discrimination threshold; ie. they have a minimum starting flow.

3.5
error
result of a measurement minus a true value of the measurand

NOTE 1 Since a true value cannot be determined, in practice a conventional true value is used.

NOTE 2 When it is necessary to distinguish “error” from “relative error”, the former is sometimes called “absolute error of measurement”. This should not be confused with “absolute value of error”, which is the modulus of the error.

3.6
experimental standard deviations
quantity characterizing the dispersion of the results of a series of n measurements of the same measurand

3.7
flowmeter
flow-measuring device which indicates the measured flowrate

3.8
hysteresis
property of a flowmeter whereby its response to a given stimulus depends on the sequence of the preceding stimuli

NOTE 1 Hysteresis may be expressed quantitatively as the maximum difference between the value of the measurand when the stimulus is increasing and the value of the measurand when the stimulus is decreasing

NOTE 2 Hysteresis may be quoted in terms of the measurand or, more usually, as a percentage given by the equation

3.9
K-factor
output signal of a flowmeter, expressed in number of pulses per unit quantity

NOTE Where required, this term may carry a subscript to show the unit quantity (e.g. Km -factor for pulses per unit mass, Kv-factor for pulses per unit volume).

3.10
measuring range/ working range
set of values of a measurand for which the performance of a flowmeter is intended to lie within specified limits

3.11
repeatability
value below which the absolute difference between two single successive test results obtained with the same flowmeter on the same fluid under the same conditions (same operator, same test facility, and a short interval of time, but without disconnecting or dismounting the flowmeter) can be expected to lie with a probability of 95 %

NOTE The method for calculating repeatability is given in annex A.

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3.12
span
modulus of the difference between the two limits of a nominal range of a flowmeter

EXAMPLE Nominal range —10 l/s to +10 l/s; span 20 l/s.

3.13
stability
ability of a flowmeter to maintain constant its metrological characteristics

NOTE It is usual to consider stability with respect to time. Where stability with respect to another quantity is considered, this should be stated explicitly.

3.14
traceability
property of the result of a measurement or the value of a standard whereby it can be related to stated references, usually national or International Standards, through an unbroken chain of comparisons, all having stated uncertainties

NOTE See clause 5

3.15
uncertainty of measurement
estimate characterizing the range of values within which the true value of the measurand lies

NOTE Uncertainty of measurement comprises, in general, many components. Some of these components may be estimated on the basis of the statistical distribution of the results of series of measurements and can be characterized by experimental standard deviations. Estimates of other components can only be based on experience or other information.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at http://www.iso.org/obp

4 General requirements

The flowmeter specification shall enable the potential user to predict the flowmeter's performance at any flowrate and environmental condition within the limits of the specification. In this context, environment includes not only climatic conditions but any other operating conditions or disturbances which influence performance, e.g. pressure of the fluid, configuration of the conduit, presence of impurities in the fluid.

The term "flowmeter" refers to the total flowmeter package which may comprise a primary and a secondary device, specified by the manufacturer. The technical specifications shall give a clear description of the "flowmeter" to which the performance specifications refer, together with a reference or order number by which they can be related to a particular flowmeter or model of flowmeter. Compliance with relevant International Standards should be indicated and these may refer to the flowmeter as defined in the technical specification or to individual components.

The traceability group of the flowmeter shall always be given (see clause 8). Only terms defined in this national Standard shall be used in the performance specification and they shall be accompanied by statements of traceability and conditions of use. If it is essential for any other new or trade terms to be employed, they shall be carefully defined in order to make their meaning absolutely clear.

In the calibration of a flowmeter, it is essential that the terms “dry calibration” and “wet calibration” NOT be used. If the performance of a flowmeter is theoretically predicted, then this fact should be stated together with the method of prediction.

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Repeatability shall be calculated in accordance with annex B.

5 Traceability

Any performance specification produced by the manufacturer shall be accompanied by a statement of how the specification was produced, with reference being made to relevant national or International Standards.

A statement of the “traceability group” of the flowmeter (see clause 8) should include additional information on the test sample size, any quality assurance standard used and the traceability (e.g. to national or International Standards) of the measurements taken in determining the calibration.

6 Uncertainty of flow measurement

Statements of the uncertainty of measurement of a flowmeter shall be accompanied by a record of the condition limits at which the uncertainty was derived. If the device is used outside these limits, the uncertainty does not strictly apply.

The uncertainty shall be calculated in accordance with DUS ISO 5168.

EXAMPLE Uncertainty: ±1 % of measured flowrate (calculated in accordance with ISO 5168 using the root-sum-square method to give 95 % coverage)

Calibration: 50 m3/h to 1000 m3/h at 500 kPa, 20 °C on air (in accordance with DUS 2160:2019, traceability group A1).

7 Conditions of use

7.1 Measuring range

The range of properties over which the manufacturer has designed the flowmeter to operate such that the performance is within the specified limits shall be clearly stated. This shall include relevant environmental/operational conditions such as ambient temperature, fluid type and pressure, etc.

EXAMPLE Fluid Natural gas

Measuring range 20 m3/h to 1000 m3/h

Maximum working pressure 1500 kPa

Fluid temperature range —15 °C to +20°C

Permissible ambient temperature —15 °C to +60°C.

7.1 Uncertainty over measuring range

The specification shall enable the user of a flowmeter to predict the uncertainty of the flow measurement at any flow within the measuring range. Use of a flowmeter outside the measuring range will undoubtedly give rise to an increase in uncertainty.

The environmental/operational conditions in which the flowmeter operates may also affect the uncertainty of the measurement. Therefore a table of flows, environmental conditions and consequent uncertainty values may be required. The table should be drawn up so that the uncertainty of measurement can be easily established for any combination of the flow and environmental conditions within the specified limits.

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Where the uncertainty of measurement is not significantly affected by environmental conditions, a table relating flow to uncertainty is acceptable. In many cases only two values are required, viz.:

a) uncertainty as a percentage of flow, for flow within a specified range, and

b) uncertainty as a numerical value, for flows below a specified value.

If it is necessary to express uncertainty as a percentage of full-scale flow, this full-scale flow shall be stated.

8 Traceability group

8.1 General

In order to specify uncertainty of measurement (see clause 6), the systematic uncertainty must be estimated. This can only be done if either a calibration has been undertaken or a large amount of calibration data exists for the type of flowmeter concerned.

If the flowmeter performance specification specifies the uncertainty of measurement, then the traceability group into which the flowmeter falls shall be stated as shown.

8.2 Traceability Group A: calibrated in an Accredited Calibration Laboratory

Flowmeters in this group are calibrated in an Accredited Laboratory by comparison with another flowmeter, or by some other means of calibration, traceable to national standards.

NOTE The criteria to be satisfied by an Accredited Laboratory are given in ISO/IEC Guide 25.

This traceability group is subdivided thus:

a) **Traceability Group A1**: every flowmeter calibrated

Every flowmeter in this group is calibrated as described above. Each flowmeter shall be supplied with a calibration certificate or report stating the associated uncertainty of calibration.

b) **Traceability Group A2**: a sample of flowmeters calibrated

Flowmeters in this group are calibrated using a recognized batch testing or Quality Assurance procedure. The method or procedure used shall be stated. Flowmeters tested by an ad hoc batch testing method are not included in this group

8.3 Traceability Group B: calibrated against a traceable standard in a non-accredited laboratory

Flowmeters in this group are calibrated in a non-accredited laboratory by comparison with another flowmeter which itself has a calibration traceable to national standards, or by some other means of calibration using equipment which has a calibration that is traceable to national standards.

This group is subdivided into traceability groups B.1 and B.2 as described for traceability groups A.1 and A.2

8.4 Traceability Group C: calibrated against a non-traceable standard

Flowmeters in this group are calibrated as for traceability group B, but by reference to the manufacturer's or other body's standards. Traceability to national standards cannot be quoted, but a calibration certificate which indicates the calibration source and the associated uncertainty may be issued.

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This group is subdivided into traceability groups C1 and C2 as described for traceability groups A1 and A2.

8.5 Traceability Group D: manufactured in accordance with an International Standard

Flowmeters in this group are not calibrated as described in traceability groups A or B, but are manufactured in accordance with a relevant International Standard which specifies the associated uncertainty. The International Standard used shall be stated (e.g. ISO 5167-1).

8.6 Traceability Group E: type-tested

An early or pre-production batch of flowmeters in this group are calibrated to establish a typical uncertainty. The flowmeter specification may then quote a typical uncertainty.

8.7 Traceability Group F: uncalibrated

Flowmeters in this group are not calibrated or built to a standard which allows the estimation of uncertainty. As such, no statement of the uncertainty of measurement can be ascribed to them

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Annex A
(normative)

Repeatability

A.1 Calculation of repeatability

To determine repeatability the following steps shall be followed.

The test conditions shall be kept constant throughout the test period. Failure to do so will result in an apparent increase in repeatability.

Set the flowrate so that the maximum value of repeatability over the specified measuring range is obtained; this is generally just below the maximum or just above the minimum flowrate of the specified measuring range.

a) Obtain a set of consecutive flowrate readings preferably containing a minimum of 30 values (for less than 30 readings, repeatability generally increases with decreasing number of readings).

(For integrating flowmeters, flowrate may be obtained by noting the volume or mass passed in a suitable time period.)

Calculate the experimental standard deviation, s, of these values using the equation:

$$s = \sqrt{\frac{\sum_{i=1}^{n}\left(x_i - \bar{x}\right)^2}{(n-1)}}$$

Where;

xi is the i-th flowrate value, and

x is the arithmetic mean of the n values considered.

b) When 30 or more values have been used to estimate the standard deviation, calculate the repeatability, r, using the equation:

r = 2,83 s

c) When less than 30 values have been used to estimate the standard deviation, calculate the repeatability, r,using the equation:

r = $t_{95}\sqrt{2}.s$

where t_{95} is Student's t for 95 % coverage and can be found from statistical tables for *n*-1 degrees of freedom or from Table B.1.

c) If it is suspected that the set of flowrate readings contains spurious values (outliers), these may only be removed from the set of readings if they have been identified using a standard statistical outlier test as detailed in ISO 5168

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A.2 Presentation of results

Repeatability may be presented in absolute terms or as a percentage of the flowrate:

Repeatability: r = 0.15 kg/h
(calculated in accordance with DUS 2160:2160)

OR

Repeatability: r = 0.06 % of reading
(calculated in accordance with DUS 2160:2019)

Table B.1 — Student's *t* values (*t*95)

Degrees of freedom (*n*-1)	*t*95	Degrees of freedom (*n*-1)	*t*95
1	12,706	16	2,120
2	4,303	17	2,110
3	3,182	18	2,101
4	2,776	19	2,093
5	2,571	20	2,086
6	2,447	21	2,080
7	2,365	22	2,074
8	2,306	23	2,069
9	2,262	24	2,064
10	2,228	25	2,060
11	2,201	26	2,056
12	2,179	27	2,052
13	2,160	28	2,048
14	2,145	29	2,045
15	2,131	•	1,96

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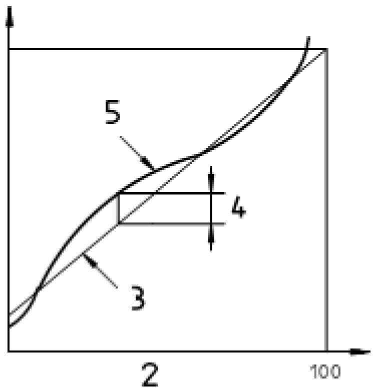
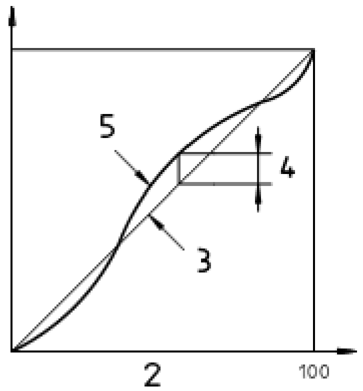
Annex B
(informative)

Illustrations of linearity

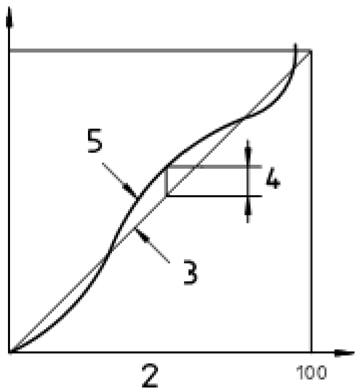
The forms of the graphs in Figure B.1 a), b) and c) are generalized to illustrate the three different expression of linearity



a) Independent linearity



b) Terminal-based linearity



c) Zero-based linearity

Key

1 Response (% span)
2 Stimulus (% span)
3 Straight line
4 Maximum deviation
5 Actual result

Figure B.1 — Different expressions of linearity

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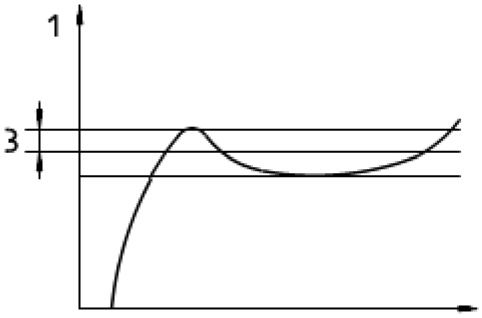
Figure B.2 shows a typical turbine meter characteristic as an example of how linearity might be used in practice. This illustrates independent linearity in which the straight line has been positioned so as to minimize the deviation over a range and to give a constant K-factor



Key

1 K-factor (pulses/unit volume)
2 Flowrate, Q (% span)
3 Maximum deviation

Figure B.2 — Typical application of independent linearity

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Bibliography

[1] ISO 3534-1, Statistics — Vocabulary and symbols — Part 1: Probability and general statistical terms.

[2] ISO 4006, Measurement of fluid flow in closed conduits — Vocabulary and symbols.

[3] ISO/TR 7066-1, Assessment of uncertainty in the calibration and use of flow measurement devices — Part 1: Linear calibration relationships.

[4] ISO 7066-2, Assessment of uncertainty in the calibration and use of flow measurement devices — Part 2: Non- linear calibration relationships.

[5] ISO Guide 25, General requirements for the competence of calibration and testing laboratories.

[6] IEC 60770, Methods of evaluating the performance of transmitters for use in industrial-process control systems.

[7] International Vocabulary of Basic and General Terms in Metrology (VIM), BIPM/IEC/ISO/OIML, 1993

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