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Vacuum technology — Vacuum gauges — Specifications, calibration and measurement uncertainties for capacitance diaphragm gauges

Technique du vide — Manomètres à vide — Spécifications, étalonnage et incertitudes de mesure des manomètres capacitifs à membrane

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical Committee ISO/TC 112, *Vacuum technology*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

ISO 3567, *Calibration by direct comparison with a reference gauge*, and ISO 27893, *Evaluation of the uncertainties of results of calibrations by direct comparison with a reference gauge*, were published in 2011 and in 2009, respectively. Detailed guidance for a specific gauge is intended to be given in separate international standards or technical specifications for the calibration of special types of gauges.

This document complements ISO 3567 and ISO 27893 when characterizing, calibrating or using capacitance diaphragm gauges (CDGs) as reference gauges.

CDGs are widely used to measure pressures in the medium vacuum up to atmospheric pressure. For the dissemination of the pressure scale and measurement of low and medium vacuum pressures by this gauge, the relevant parameters, calibration guidelines and uncertainties are described in this document.

Vacuum technology — Vacuum gauges — Specifications, calibration and measurement uncertainties for capacitance diaphragm gauges

1 Scope

This document defines terms related to capacitance diaphragm gauges (CDGs), specifies which parameters have to be given for CDGs, details their calibration procedure and describes which measurement uncertainties have to be considered when operating these gauges.

This document complements ISO 3567 and ISO 27893 when calibrating CDGs and using them as reference standards.

2 Normative references

The following documents are 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.

ISO 3529-1, *Vacuum technology — Vocabulary — Part 1: General terms*

ISO 3529-3, *Vacuum technology — Vocabulary — Part 3: Total and partial pressure vacuum gauges*

ISO 3567, *Vacuum technology — Vacuum gauges — Calibration by direct comparison with a reference gauge*

ISO 27893, *Vacuum technology — Vacuum gauges — Evaluation of the uncertainties of results of calibrations by direct comparison with a reference gauge*

ISO/IEC Guide 98-3, *Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

ISO/IEC Guide 99, *International vocabulary of metrology — Basic and general concepts and associated terms (VIM)*

3 Terms and definitions

For the purposes of this document the terms and definitions given in ISO 3529-1, ISO 3529-3, ISO 3567, ISO 27893, ISO/IEC Guide 98-3, ISO/IEC Guide 99 and the following apply.

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

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

— IEC Electropedia: available at http://www.electropedia.org/

3.1 Components

3.1.1
diaphragm
membrane
elastic element which deforms under differential pressure applied to it

3.1.2
measurement side
side of diaphragm on a CDG to which the pressure to be measured is applied

Note 1 to entry: Sometimes the measurement side is called the test side.

3.1.3
reference side
side of diaphragm on a CDG opposite the measurement side

3.1.4
absolute-type CDG
CDG where the reference side is permanently evacuated

3.1.5
differential-type CDG
CDG where the reference side is accessible from outside

3.1.6
measurement port
port connecting to the measurement side of a CDG

3.1.7
reference port
port connecting to the reference side of a CDG

Note 1 to entry: In absolute-type CDG, this port does not exist.

3.1.8
integrated type CDG
gauge in which the head and controller form one piece of equipment

3.2 Physical parameters

3.2.1
reproducibility
long-term instability
δ_t
relative quantity characterizing the typical change of measurement error near full scale (90% to 100% of full scale) of the CDG (nitrogen) after a specified period

Note 1 to entry: Reproducibility can be determined in two ways:

a) as the relative standard deviation of measurement error Δp_i obtained from at least three calibrations each being separated by the specified period

$$\delta_t = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}\left(\frac{\Delta p_i}{p_i} - \overline{\left(\frac{\Delta p}{p}\right)}\right)^2} \tag{1}$$

where

n is the number of calibrations, i;

$$\overline{\left(\frac{\Delta p}{p}\right)} = \frac{1}{n}\sum_{i=1}^{n}\frac{\Delta p_i}{p_i}.$$

b) as the mean of absolute (non-negative) changes of measurement error Δp_i between recalibrations separated by the specified period

$$\delta_t = \frac{\sum_{i=1}^{n-1} \left| \frac{\Delta p_{i+1}}{p_{i+1}} - \frac{\Delta p_i}{p_i} \right|}{n-1} \tag{2}$$

and n as described above. Formula (1) is recommended when the measurement error does not show a significant drift but random variations, Formula (2) when the measurement error shows a systematic and monotonic drift. In both cases, δ_t shall be accompanied with the specified time period, for example δ_t per year or δ_t per two years.

Note 2 to entry: If the output signal of the gauge is not pressure (but e.g. voltage or current), this signal shall be converted to pressure according to specification, before the measurement error is calculated.

Note 3 to entry: Reproducibility can be determined by recalibrations with a more accurate gauge or a primary standard. This often requires a transport which itself can lead to an instability of the calibrated value. For this reason, it is not reasonable to assume a linear relationship of instability with time (e.g. δ_t for a period of two years is not two times δ_t for a period of one year).

Note 4 to entry: If not specified otherwise, it is recommended that δ_t is determined over a period of one year. This is usually a reasonable compromise between costs and influence of transport on the one hand and a possible drift and lowest possible measurement uncertainty on the other hand.

Note 5 to entry: Measurement error is defined in 3.3.3.

3.2.2

warm-up period

duration between the instant after which the power supply is energized and the instant when the measuring instrument is used to the expected measurement uncertainty as specified

Note 1 to entry: For a CDG with controlled temperature type gauge head, the time to achieve and stabilize the temperature of the gauge head shall be considered. For a gauge head without temperature control, the time to stabilize the temperature due to the heat generated from the electrical circuit equipped in the gauge head shall be considered.

Note 2 to entry: Warm-up period depends on, for example, the environment of the measurement or the equipment.

3.2.3

response time

time from a sudden change of an applied pressure until the corresponding change of an indication of the CDG has reached a specified fraction of its final value

Note 1 to entry: The amount of the change is specified. There are three variations of the corresponding change of the indication: 0 % to 90 %; 0 % to 63,2 %; 10 % to 90 %.

3.2.4

update interval

time interval at which an output of a CDG is updated

3.2.5

admissible pressure

maximum load pressure

maximum differential pressure that can be applied to the CDG while operating within its stated specifications

Note 1 to entry: When pressure above the admissible pressure is applied to a gauge head, the gauge head is required for recalibration.

3.2.6

disruption pressure

burst pressure

pressure applied to the gauge head above which a gauge head can fail

3.2.7
internal volume
volume of measurement (and reference side, if applicable) side in the gauge head up to the sealing plane of the measurement (and reference) port

3.3 Other parameters

3.3.1
measurement uncertainty
non-negative parameter characterizing the dispersion of the quantity values being attributed to a measurand, based on the information used

Note 1 to entry: Measurement uncertainty includes components arising from systematic effects, such as components associated with corrections and the assigned quantity values of measurement standards, as well as the definitional uncertainty. Sometimes small estimated systematic effects are not corrected for but, instead, associated measurement uncertainty components are incorporated.

Note 2 to entry: The parameter can be, for example, a standard deviation called standard measurement uncertainty (or a specified multiple of it), or the half-width of an interval, with a stated coverage probability.

Note 3 to entry: Measurement uncertainty comprises, in general, many components. Some of these can be evaluated by Type A evaluation of measurement uncertainty from the statistical distribution of the quantity values from a series of measurements and can be characterized by standard deviations. The other components, which can be evaluated by Type B evaluation of measurement uncertainty, can also be characterized by standard deviations, evaluated from probability density functions based on experience or other information.

Note 4 to entry: In general, for a given set of information, it is understood that the measurement uncertainty is associated with a stated quantity value attributed to the measurand. A modification of this value results in a modification of the associated uncertainty.

[SOURCE: ISO/IEC Guide 99:2007, 2.26]

3.3.2
measurement accuracy
closeness of agreement between a measured quantity value and a true quantity value of a measurand

Note 1 to entry: The concept 'measurement accuracy' is not a quantity and is not given a numerical quantity value. A measurement is said to be more accurate when it offers a smaller measurement error.

Note 2 to entry: The term “measurement accuracy” should not be used for measurement trueness and the term “measurement precision” should not be used for 'measurement accuracy', which, however, is related to both these concepts.

Note 3 to entry: 'Measurement accuracy' is sometimes understood as closeness of agreement between measured quantity values that are being attributed to the measurand.

Note 4 to entry: In the past and up to now, “accuracy of a CDG” is one of the important parameters given by manufacturers and has been published on the data sheets of many manufactures. Their definition of accuracy is a numerical value and included nonlinearity, repeatability, hysteresis and the difference in measurement error between a CDG and the reference standard used for calibration. It did not include the measurement uncertainty of the reference standard. For these reasons, this term is in contradiction to the above definition given in the VIM and should not be used.

[SOURCE: ISO/IEC Guide 99:2007, 2.13, modified — Note 4 to entry added.]

3.3.3
measurement error
measured quantity value minus a reference quantity value

Note 1 to entry: The concept of 'measurement error' can be used both a) when there is a single reference quantity value to refer to, which occurs if a calibration is made by means of a measurement standard with a measured quantity value of a negligible measurement uncertainty or if a conventional quantity value is given, in which case the measurement error is known, and b) if a measurand is supposed to be represented by a unique true quantity value or a set of true quantity values of negligible range, in which case the measurement error is not known.

Note 2 to entry: Measurement error should not be confused with production error or mistake.

[SOURCE: ISO/IEC Guide 99:2007, 2.16]

3.3.4
measurement precision
closeness of agreement between indications or measured quantity values obtained by replicate measurements on the same or similar objects under specified conditions

Note 1 to entry: Measurement precision is usually expressed numerically by measures of imprecision, such as standard deviation, variance, or coefficient of variation under the specified conditions of measurement.

Note 2 to entry: The 'specified conditions' can be, for example, repeatability conditions of measurement, intermediate precision conditions of measurement, or reproducibility conditions of measurement (see ISO 5725-1:1994).

Note 3 to entry: Measurement precision is used to define measurement repeatability, intermediate measurement precision, and measurement reproducibility.

Note 4 to entry: Sometimes "measurement precision" is erroneously used to mean measurement accuracy.

[SOURCE: ISO/IEC Guide 99:2007, 2.15]

3.3.5
measurement repeatability
measurement precision under a set of repeatability conditions of measurement

[SOURCE: ISO/IEC Guide 99:2007, 2.21]

3.3.6
measurement reproducibility
measurement precision under reproducibility conditions of measurement

Note 1 to entry: Relevant statistical terms are given in ISO 5725-1:1994 and ISO 5725-2:1994.

[SOURCE: ISO/IEC Guide 99:2007, 2.25]

3.3.7
measurement trueness
closeness of agreement between the average of an infinite number of replicate measured quantity values and a reference quantity value

Note 1 to entry: Measurement trueness is not a quantity and thus cannot be expressed numerically.

Note 2 to entry: Measurement trueness is inversely related to systematic measurement error, but is not related to random measurement error.

Note 3 to entry: "Measurement accuracy" should not be used for 'measurement trueness'.

[SOURCE: ISO/IEC Guide 99:2007, 2.14, modified — Note 1 to entry revised.]