
**Vacuum gauges — Calibration by direct
comparison with a reference gauge**

*Manomètres — Étalonnage par comparaison directe avec un
manomètre de référence*

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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.

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 3567 was prepared by Technical Committee ISO/TC 112, *Vacuum technology*.

This first edition of ISO 3567 cancels and replaces ISO/TS 3567:2005, of which it constitutes a technical revision.

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Introduction

The purpose of this International Standard is to establish the physical, technical and metrological conditions necessary for adequately disseminating the pressure scale in the vacuum regime by calibration with a reference gauge. It is assumed that the user will be familiar with the general procedures of vacuum generation and measurement in the vacuum ranges considered.

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Vacuum gauges — Calibration by direct comparison with a reference gauge

1 Scope

This International Standard specifies the physical, technical and metrological conditions to be fulfilled when calibrations of vacuum gauges are performed by direct comparison with a reference gauge. From the conditions described, the design of an apparatus that can perform vacuum gauge calibrations in an adequate manner can be deduced.

The vacuum gauges to be calibrated can be of any kind. Many types of gauges consist of several parts. Typically, these are: gauge head, cable, operational device and signal read out. This entire set is considered as the unit that has to be calibrated. Whereas, if only the gauge head (i.e. the part of the vacuum gauge directly exposed to the vacuum) is calibrated, all set-ups and conditions would have to be recorded such that the user of the calibrated gauge head would be able to perform the measurements in the same manner as during the calibration.

The reference gauge is either a calibrated gauge, traceable to a vacuum primary or national standard (normal case), with a calibration certificate according to ISO/IEC 17025, or an absolute measuring instrument (rare case), traceable to the SI units and to which a measurement uncertainty can be attributed.

This International Standard does not give guidance on how to treat special types of vacuum gauges, be they reference standards or units under calibration; it is intended that such guidance be given in other International Standards.

The pressure range for calibrations treated in this International Standard depends on the realized design of the calibration apparatus and on the type of reference gauge. The range varies in its limits from 10^{-6} Pa to 110 kPa.

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

ISO/IEC 17025:2005, *General requirements for the competence of testing and calibration laboratories*

3 Terms and definitions

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

3.1

primary standard

measurement standard established using a primary reference measurement procedure

[SOURCE: ISO/IEC Guide 99:2007, 5.4, modified]

3.2

national standard

measurement standard recognized by national authority to serve in a state or economy as the basis for assigning quantity values to other measurement standards for the kind of quantity concerned

[SOURCE: ISO/IEC Guide 99:2007, 5.3]

**3.3
reference standard**

measurement standard designated for the calibration of other measurement standards for quantities of a given kind in a given organization or at a given location

[SOURCE: ISO/IEC Guide 99:2007, 5.6]

NOTE In this International Standard, it is synonymous with *reference gauge*.

**3.4
vacuum gauge**

instrument for measuring gas or vapour pressure that is less than the prevailing atmospheric pressure

[SOURCE: ISO 3529-3:1981, 3.1.2]

NOTE 1 Some types of vacuum gauges commonly in use do not measure a pressure directly, but measure some other physical quantity which, under specific conditions, is related to pressure.

NOTE 2 For terms and definitions of the various vacuum gauges in use, see ISO 3529-3.

**3.5
gauge head**

part of the gauge which contains the pressure-sensitive element and which is directly connected to the vacuum system

NOTE A gauge head comprising its operational device is usually called a *transmitter*.

[SOURCE: ISO 3529-3:1981, 3.1.2.1, modified]

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**3.6
operational device**

part of a vacuum gauge that operates the gauge head and/or delivers the signal related to pressure

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**3.7
unit under calibration
UUC**

vacuum gauge to be calibrated

**3.8
entrance flange**

flange by which the unit under calibration or the reference gauge is connected to the calibration chamber

**3.9
calibration chamber**

vacuum chamber that serves as a common vacuum medium for the reference gauge and unit under calibration

**3.10
entrance mouth**

opening in the calibration chamber which leads to a unit under calibration, reference gauge or any other part of the calibration system

**3.11
calibration gas**

gas species or mixture that is used to change the pressure in the calibration chamber

**3.12
sorption**

taking up of a gas or vapour by a solid or liquid

**3.13
desorption**

liberation of gases or vapours sorbed by a material

3.14**outgassing rate**

rate at which molecules and atoms desorb from a material exposed to a vacuum

3.15**total pressure**

p

sum of pressures of all the components of a gaseous mixture

NOTE A vacuum is usually measured as the absolute pressure of gas prevalent in an enclosed chamber, expressed in pascals (Pa) or millibars (mbar): 1 mbar = 100 Pa; 1 bar = 0,1 MPa = 10^5 Pa; 1 MPa = 1 N/mm².

3.16**residual pressure**

lowest pressure that can be reached in the calibration chamber, typically after 24 h of pumping

NOTE The residual pressure depends, among others things, on the bake-out condition of the calibration chamber.

3.17**base pressure**

pressure in the calibration chamber that exists either before gas is admitted into the calibration chamber for calibration, or later, after the gas inlet valve has been turned off for some time

NOTE The base pressure can be higher than the residual pressure, but cannot be lower.

4 Symbols and abbreviated terms

D	diameter of cylinder, expressed in millimetres (mm)
e	error of reading
p	total vacuum/pressure, expressed in pascals (Pa) or millibar (mbar)
p_0	base pressure, expressed in pascals (Pa) or millibar (mbar)
p_{cal}	calibration pressure, expressed in pascals (Pa) or millibar (mbar)
p_{ind}	indicated pressure, expressed in pascals (Pa) or millibar (mbar)
p_{res}	residual pressure, expressed in pascals (Pa) or millibar (mbar)
Q_{out}	outgassing rate, expressed in pascal litres per second (Pa · L/s), pascal cubic metres per second (Pa · m ³ /s) or millibar litres per second (mbar · L/s)
$q_{v,eff}$	effective volume flow rate of the pump — effective litres per second (L/s) or cubic metres per second (m ³ /s) volume flow rate into pump
S	sensitivity (coefficient) (Pa ⁻¹)
u	standard uncertainty
U	expanded uncertainty
CF	correction factor
UUC	unit under calibration

5 General principle

The UUC is connected to the same calibration chamber as the reference gauge.

Calibration of a vacuum gauge — the UUC — by comparison with a reference gauge is done by exposing the entrance flange of the UUC and that of the reference gauge to the same density and velocity distribution of calibration gas molecules. The same density and velocity distribution of these molecules means the same pressure at the two locations, but not vice versa. Since there are many types of vacuum gauge that do not measure pressure — but instead, for example, gas density or the impingement rate of gas molecules — the above requisite is both necessary and more stringent than only calling for equal pressures at the two entrance flanges.

The gas density (pressure) in the calibration chamber can be varied and the gauge readings of the UUC compared with the pressures indicated by the reference gauge.

From this general principle, the requirements (see Clause 6) for the design of the calibration apparatus are deduced.

6 Requirements

6.1 Design of calibration chamber

The chamber shall be designed to ensure that the distribution of gas in the measuring volume is sufficiently uniform in space and stable in time.

In addition, the material of the calibration chamber shall be chosen such that the residual pressure, p_{res} , determined by the effective pumping speed, $q_{v,eff}$ (effective volume flow rate into pump), and the total outgassing rate in the calibration chamber, Q_{out} (absence of leaks), is low enough to perform the calibrations, as expressed by Formula (1) (see also 6.3).

$$p_{res} = \frac{Q_{out}}{q_{v,eff}} \quad (1)$$

In detail, the calibration chamber shall be designed and operated as follows. However, design criteria a) to e) may be disregarded when the minimum pressures to be realized in the vacuum chamber are larger than 100 Pa and only static pressures (see 7.1) are established. Independent of pressure, criteria b) to d) may be disregarded when only static pressures are established.

- a) The calibration chamber shall have a volume of at least 20 times the total volume of all the gauges and associated pipe work connecting the chamber and the gauges (e.g. elbows shall be considered as part of the gauge volume).
- b) The shape of the calibration chamber (see Figure 1) shall be cylinder-symmetrical to at least one axis. A sphere is ideal, but two symmetrical domes, each a part of a sphere and attached to one another, or cylinders, are equally possible. Where a cylinder is used, its overall length shall be within one and two times its diameter, and domed ends are recommended.
- c) The centre of the cross-sectional area of the pumping outlet and the gas inlet (if applicable) shall lie on the same cylindrical axis of symmetry of the calibration chamber. The gas inlet may be positioned between the pump outlet and pump system (see 6.3), in which case there is no need to have the gas inlet on the axis of symmetry.
- d) All entrance mouths and their respective flanges to which either the UUCs or the reference gauges are to be connected shall be on a common equatorial plane, perpendicular to the cylindrical axis of symmetry chosen for the pumping outlet.

Where a cylinder is used, it is recommended that this equatorial plane separate the cylinder into two halves of equal length. Where a cylinder with a length of $(3/2)D$ in relation to its diameter is used (suitable

for pump speed measurements), the gauges may be placed at one third of the length ($D/2$) above the bottom flange.

- e) Temperature differences between arbitrary points across the calibration chamber shall be less than 1 K. Points closer than 5 cm from the entrance mouth to a heated vacuum gauge head (e.g. ionization gauge) may be disregarded.
- f) The spatial [see e)] mean temperature of the calibration chamber shall be $(23 \pm 3) ^\circ\text{C}$ during calibration, while the mean temperature should not change by more than 1 K.

If the design criteria a) to e) are not fulfilled, the possible correction owing to unequal molecular density and velocity distribution at the entrance flanges of the reference gauge and UUC (see 7.3) shall be measured and the uncertainty of the correction term estimated.

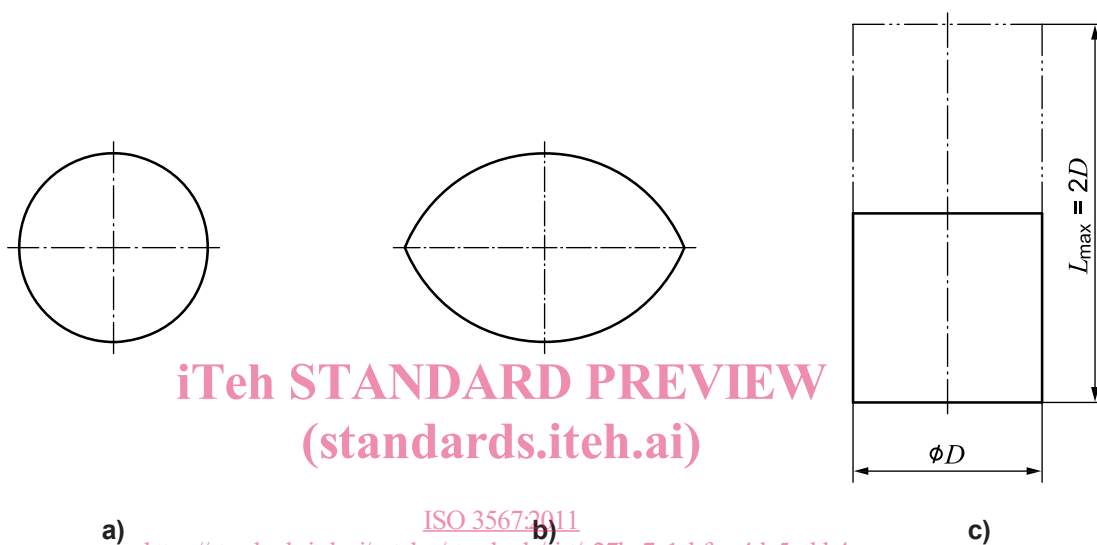


Figure 1 — Examples of possible calibration chamber shapes

6.2 Plumbing of gauges to calibration chamber

6.2.1 In order to minimize unbalanced molecular (pressure) distribution from sorption, gauge pumping and outgassing etc., the tubing connecting the calibration chamber and the gauges shall be as short as possible and shall have a diameter of at least the open area of the entrance flange of the gauge. In cases where the UUC or the reference gauge imposes a significant heat load [see 6.1 e)] on the calibration chamber, the tube length may be increased to reduce thermal conductance.

6.2.2 Care shall be taken to ensure that the simultaneous operation of the reference gauges and UUC does not result in any significant mutual influence of their respective readings in steady operation. An influence on the order of the uncertainty of the base pressure is acceptable.

NOTE The mutual influence can be checked by observing the reading of a gauge when switching another gauge off and on.

6.2.3 No significant ambient air flow cooling or heating of the UUC or reference gauge shall be present. A protective cover could be necessary.