FINAL
DRAFT

TECHNICAL
SPECIFICATION

ISO/DTS
6737

ISO/TC **112**

Secretariat: **DIN**

Voting begins on:
2023-07-07

Voting terminates on:
2023-09-01

Vacuum technology — Vacuum gauges — Characteristics for a stable ionisation vacuum gauge

Technique du vide — Manomètres à vide — Caractéristiques des manomètres à ionisation stable

Reference number
ISO/DTS 6737:2023(E)

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

Contents

Page

Foreword iv

Introduction v

1 Scope 1

2 Normative references 1

3 Terms and definitions 1

4 Symbols and abbreviated terms 2

5 General description of the design 2
5.1 Components 2
5.2 Mode of operation 3

6 Specifications of the ionisation vacuum gauge 4
6.1 General specifications and requirements for the gauge head 4
6.2 Electrical equipment 5

7 Dimensions and potentials 6
7.1 General 6
7.2 Dimensions and tolerances 7
7.3 Potentials 9
7.4 Cathode 9
7.5 Anode cage 9
7.6 Gaps between electrodes 10
7.7 Electrode materials 10
7.8 Electrical feedthroughs 10
7.9 Surrounding tube (envelope) and flanges 10
7.10 Magnetic fields 10

8 Characteristics of the gauge (informative) 11
8.1 Sensitivity 11
8.2 Linearity 11
8.3 Electron transmission efficiency 11
8.4 Residual current and resolution 11
8.5 Repeatability 11
8.6 Reproducibility 12
8.7 Interference 12
8.8 Temperature of electrodes 12
8.9 Environmental conditions 12

9 Handling of and measurement with the gauge 12
9.1 Orientation of the gauge head 12
9.2 Environmental conditions 12
9.3 Conditioning of the gauge 12
9.4 Testing 12
9.5 Warm-up time 13
9.6 Sensitivity and calibration 13
9.7 Measurement 13
9.8 Transport 13
9.9 Cathode exchange 13

Annex A (Informative) **Electron and ion trajectories of recommended gauge dimensions according to simulation** 14

Bibliography 15

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 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 document 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).

ISO draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). ISO takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, ISO had not received notice of (a) patent(s) which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at www.iso.org/patents. ISO shall not be held responsible for identifying any or all such patent rights.

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

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

The ionisation vacuum gauge is the only vacuum gauge type in the full range of high and ultrahigh vacuum.[1] Important applications need better accuracy, reproducibility and known sensitivities for many gas species, properties which all current types of ionisation vacuum gauges lack. This document provides the characteristics for a stable ionisation vacuum gauge so that this gauge is accurate, robust and long-term stable, with known sensitivity for nitrogen and known relative sensitivity factors, and can be built by any experienced manufacturer of other ionisation vacuum gauges.

Vacuum technology — Vacuum gauges — Characteristics for a stable ionisation vacuum gauge

1 Scope

This document describes a special design of an ionisation vacuum gauge which has a well-defined ionising electron path length.[2] Due to the construction design, it leads to good measurement accuracy, long-term stability, as well as gauge independent and reproducible sensitivity for nitrogen and relative sensitivity factors[3] It is designed for the measurement range of 10^{-6} Pa to 10^{-2} Pa.

This document describes only those dimensions and potentials of the gauge head which are relevant for the electron and ion trajectories. This document does not describe the electrical components necessary to operate the ionisation vacuum gauge in detail. The gauge head can be operated by voltage and power sources and ammeters commercially available, but also by a controller specially built for the purpose of the operation of this gauge head.

The ionisation vacuum gauge described in this document can be built by any experienced manufacturer of other ionisation vacuum gauges. It is not subject to intellectual property protection.

It is assumed for this document that the applicant is familiar with both the physics and principles of ionisation vacuum gauges as well as high and ultra-high vacuum technology in general.

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.

EN ISO 13920, *Welding - General tolerances for welded constructions - Dimensions for lengths and angles - Shape and position (ISO 13920:1996)*

ISO 2768-1, *General tolerances — Part 1: Tolerances for linear and angular dimensions without individual tolerance indications*

ISO 3669, *Vacuum technology — Dimensions of knife-edge flanges*

3 Terms and definitions

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

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

- ISO Online browsing platform: available at https://www.iso.org/obp
- IEC Electropedia: available at https://www.electropedia.org/

3.1
Wehnelt electrode
Wehnelt
an electrode with cylindrical symmetry around the electron emitting cathode, mainly used for focusing of the electron beam

3.2

ionisation space

the space in which ions generated by collision of gas molecules with high energy electrons reach the ion collector by means of a suitable electrostatic field

3.3

Faraday cup

metal cup or other piece of metal designed to catch charged particles in vacuum

Note 1 to entry: In the ionisation vacuum gauge described in this document, the Faraday cup is designed to capture the electrons emitted from the cathode

3.4

envelope

the metallic wall at zero (earth) potential surrounding the gauge head at least in its full length

3.5

electron transmission

the ratio of electron current measured at the Faraday cup divided by the electron current emitted from the cathode

4 Symbols and abbreviated terms

I	ion current at pressure p [A]
I_0	ion current at residual pressure p_0 [A]
I_e	electron emission current [A]
p	pressure [Pa]
p_0	residual pressure [Pa]
r_x	relative sensitivity factor as defined in ISO 27894 [1]
S	sensitivity (coefficient) [1/Pa]
S_{N2}	sensitivity for nitrogen [1/Pa]

5 General description of the design

5.1 Components

The ionisation vacuum gauge consists of the following functional parts:

a) electron emitting cathode,

b) Wehnelt electrode,

c) anode cage in two parts,

d) ion collector,

e) electron deflector,

f) Faraday cup,

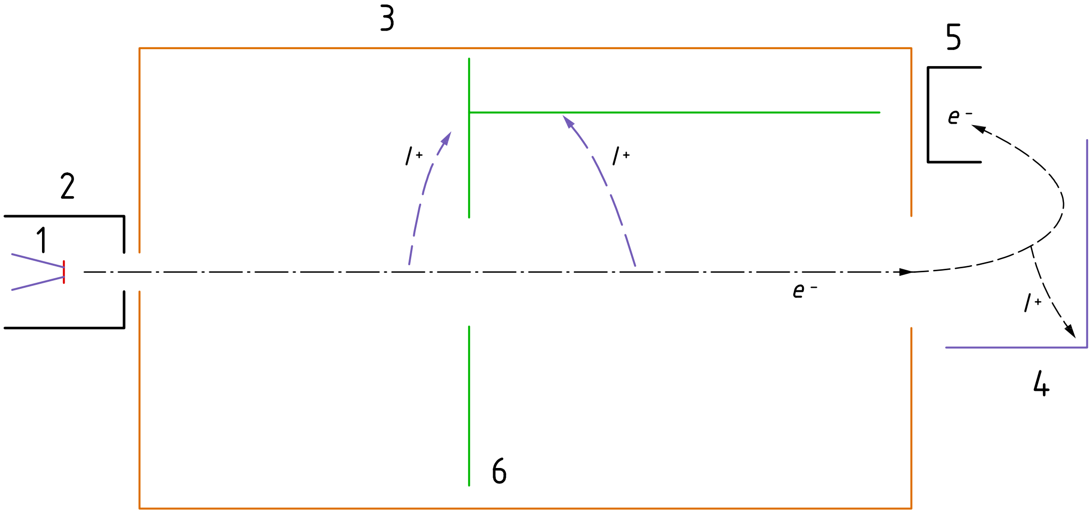
g) envelope.

The functional components a) to f) need to be exactly dimensioned.

In addition, the gauge needs electrical feedthroughs, wires, mounting parts and insulators. The gauge shall be mounted on a DN40CF or on a DN63CF flange according to ISO 3669: with corresponding tube sizes DN40 or DN63 as envelope.

5.2 Mode of operation

A schematic for the illustration of the operation of the gauge is shown in Figure 1, for a detailed drawing see Figure 2 in 7.2. For simplification, in Figure 1 the anode cage (3) is not been divided in two parts as in Figure 2 with (3a) and (3b) and the collector ring (6) in between.



Key

1	cathode with emitter disk (red)
2	Wehnelt cylinder
3	anode cage
4	electron deflector
5	faraday cup
6	ion collector
I^+	ion
e^-	electron

Figure 1 — Illustration of mode of operation (informative)

Electrons are emitted from the hot thermionic cathode (1 in Figure 1 and Figure 2), which is preferably an indirectly heated disk emitter on a potential of 50 V. The Wehnelt electrode (2 in Figure 1) surrounding the cathode has a lower potential and controls and focuses the electron beam into the opening of the anode cage at 250 V.

Note that in the future, it can be possible that the thermionic cathode can be replaced by a so-called cold field emission cathode. This cathode shall be long-term stable and provide an electron current of about 100 µA. In addition, it shall be ensured that the energy of the electrons along their path is not changed compared to the design with thermionic cathode.

Due to the penetration of the anode potential into that of the Wehnelt electrode the electrons can be extracted and accelerated into the inner part of the cylindrical anode cage. The first part of the anode cage (3a at 250 V, see Figure 2), the ion collector ring (0 V, 6 in Figure 1 and Figure 2) and the second remaining part of the anode cage (250 V, 3b in Figure 2) form an electrostatic lens which focuses the electron beam into the circular exit of the anode cage. Behind this exit the electron beam is deflected by the electron deflector electrode (45 V, 4 in Figure 1 and Figure 2) in a U-turn onto the capturing part of the Faraday cup (280 V, 5 in Figure 1 and Figure 2). When the electrons hit the Faraday cup, they will generate X-rays. By the U-turn, it is ensured that these X-rays have a very low probability to reach the ion collector or the anode where they would generate secondary electrons.

The ions generated by the electron beam inside the anode cage are accelerated towards the ion collector which consists of the mentioned ring and a rod reaching into the larger space of the anode cage. Ions generated behind the exit of the cage are accelerated towards the electron deflector electrode. The ionisation space is well defined in this design.

The measured ion current will be proportional to the gas density in contact with the electron beam, the ionisation probability of the gas molecules by the electron impacts along their path, the mean path length of the electrons inside the ionisation space and the electron current.

Due to the focused electron beam inside the anode cage, the electron current should not exceed 200 µA. Higher currents can cause non-linearities.

The mean electron path length is defined by the length of the anode cage and the potential inside it. Any changes of the emission points of the electrons on the cathode will not significantly change the path length. A replacement of the same cathode type will have an insignificant influence on the path length. Space charge effects of ions will also have an insignificant influence on the path length within the specified measurement range up to 0,01 Pa. Due to the well-defined electron path length, the nitrogen sensitivity and the relative sensitivity factors will not significantly vary from gauge to gauge except within the uncertainty due to variation of secondary electrons produced by the ion impingement on the collector[4]

As for an ionisation vacuum gauge of the extractor type, in this gauge, X-rays have a low probability of reaching the ion collector. This ensures that the secondary electron current on the ion collector produced by X-rays is rather small. Such a current would be indistinguishable from the measured ion current.

Ions desorbed by electron impact in the Faraday cup will be attracted to the electron deflector and will not reach the ion collector. Electron stimulated desorption of neutrals, however, will contribute to the gas density in the gauge and therefore to the ion current.

6 Specifications of the ionisation vacuum gauge

6.1 General specifications and requirements for the gauge head

a) The electrons shall have a direct and well-defined path from their source, the cathode, through the ionisation space to the target, the Faraday cup. The path length shall not be increased by oscillations through the ionisation space, e.g. by a magnetic field.

b) The two parts of the anode cage, the ion collector ring and the Wehnelt electrode shall have a common cylindrical axis according to best possible practice. The center of the cathode shall be aligned to this axis.

c) The electron emitting cathode shall be surrounded by a Wehnelt electrode.

d) It is recommended that the cathode is an indirectly heated disk emitter to ensure well defined and stable starting points on equal potential of the electron trajectories over the emission area.

e) The shape, dimensions, position and potentials of the anode cage, Wehnelt electrode and electron emitting part of the cathode shall be such that the emitted electrons are accelerated parallel to or with a small maximum angle (typically < 5°) to the cylindrical axis described in b).

f) The two parts of the anode cage and the ion collector ring shall form an electrostatic lens for the electrons to focus them to the circular exit of the anode cage. The electron beam shall be focused in such a way that less than 5 % of the total electron current hits the anode cage. The collector electrode consists of a ring with a long rod reaching into the anode cage in the direction of the Faraday cup.

g) It is necessary that openings in the cylindrical anode cage allow a free exchange of molecules inside and outside of the cage so that there is no significant difference in gas density. This can be achieved by slotted holes or similar. It is, however, required that there is no significant potential penetration from the envelope into the anode cage.

h) The electron beam shall be captured by a Faraday cup located behind the exit of the anode cage. The area of impact of the electrons shall be located such that generated X-rays have no direct line of sight to the ion collector. This is achieved by a deflector electrode which directs the electron beam onto a suitable target spot of the Faraday cup.

i) The electrical insulation of the ion collector to the anode cage parts shall have a total resistance (surface and bulk) such that the leakage current across them contributes with less than 0,4 % to the measured ion current at 10^{-6} Pa of nitrogen.

NOTE 1 With dimensions and potentials described in Clause 7, at 30 µA emission current, the collector current amounts to 10 pA at 10^{-6} Pa of nitrogen, so that 0,4 % correspond to 40 fA. To achieve this, a guard electrode is helpful.

j) The attachment of the gauge electrodes shall be such that their positions against each other are not changed during a transport of the gauge. Also, the stiffness of the electrodes shall be such that their shape is not changed during transport. Before and after a test according to ISTA 2A:2011, the sensitivity for nitrogen near 1 mPa is to be reproduced within 2 % (k = 2 according to GUM: ISO/IEC Guide 98-1). The test should be performed 3 times or more.

NOTE 2 It is sufficient to perform the ISTA 2A:2011 test with a single gauge after development of a prototype by a manufacturer.

k) The envelope shall be a cylindrical tube as for UHV components and cover the full length of the gauge parts plus 10 mm in length in both directions. It is recommended to close the cylinder with a grid or similar as equipotential plane. It is recommended to attach two CF flanges at the ends of the envelope tube.

l) The whole gauge head shall withstand bake-out temperatures of at least 250 °C.

m) No ferromagnetic material should be used in the gauge head except for feedthroughs (see 7.8) and the envelope (see 7.9).

All the specifications above are met by the mandatory and recommended dimensions and potentials described in Clause 7.

6.2 Electrical equipment

The voltage output of the power supplies must supply voltages between 25 V and 300 V. The cathode, Wehnelt and deflector voltages shall be stable within ±0,2 V, anode and Faraday voltages within ±0,4 V.

The power supply for the heating current of the thermionic cathode shall be on high potential of 50 V and provide enough heating power for the cathode in use to provide an emission current of up to 200 µA.

It is recommended that the total emission current (on anode and Faraday cup) be either measured with a standard uncertainty of 0,3 % or controlled within a standard uncertainty of 0,3 %.

NOTE 1 Due to some misalignment or scattering, a small, but unwanted part of electrons can reach the anode. These electrons and secondary electrons can also ionise gas molecules and contribute to the ion current.

Also, it is recommended that the current from collector to ground is measured with a standard uncertainty of 0,3% in the range of nitrogen pressure from 10^{-6} Pa to 10^{-2} Pa.

NOTE 2 With dimensions and potentials described in 7, at 30 µA emission current, the collector current ranges from about 10 pA to 100 nA.

It is permissible to use current measuring instruments with higher uncertainties. To the extent of their higher uncertainties, this will increase the uncertainty of pressure measurement. If either or both currents are measured with a standard uncertainty of more than 2 %, the uncertainty of nitrogen sensitivity and relative gas sensitivity factors given in 8.1 is exceeded for some gas species and an individual calibration of the gauge can be necessary (see also 9.6).