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

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

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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 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).

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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 type of vacuum gauge covering 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.

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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][4]}. 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
S	sensitivity (coefficient) [1/Pa]
S_{N_2}	sensitivity for nitrogen [1/Pa]

5 General description of the design

5.1 Components

The ionisation vacuum gauge consists of the following functional parts:

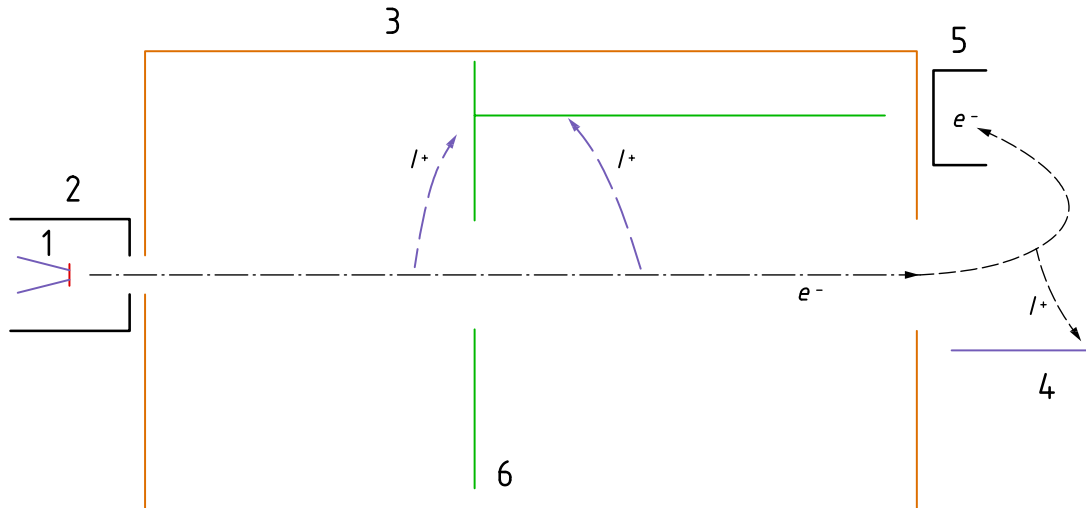
- a) electron emitting cathode,
- b) Wehnelt electrode,
- c) anode cage in two parts,
- d) ion collector,
- e) electron deflector,
- f) Faraday cup,
- g) envelope.

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 (see 7.9).

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) has not been divided in two parts as in Figure 2 with (3a) and (3b) and the collector ring (6) in between (see also Figure 3).



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

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Figure 1 — Simplified 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 in the ionization space 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.^[3]

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 $< 5^\circ$) 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 to efficiently collect ions from inside of the electron beam.
- 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.