

Gas analyzers — Expression of performance —

Part 3: Paramagnetic oxygen analyzers

The European Standard EN 61207-3:2002 has the status of a British Standard

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National foreword

This British Standard is the official English language version of EN 61207-3:2002. It is identical with IEC 61207-3:2002, including Corrigendum 1:January 2003 and Corrigendum 2:May 2003.

The UK participation in its preparation was entrusted by Technical Committee GEL/65, Measurement and control, to Subcommittee GEL/65/4, Process instruments for gas and liquid analysis, which has the responsibility to:

- aid enquirers to understand the text;
- present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;
- monitor related international and European developments and promulgate them in the UK.

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Part 3: Paramagnetic oxygen analyzers
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Foreword

The text of document 65D/79/FDIS, future edition 2 of IEC 61207-3, prepared by SC 65D, Analyzing equipment, of IEC TC 65, Industrial-process measurement and control, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 61207-3 on 2002-05-01.

This European Standard supersedes EN 61207-3:1999.

The following dates were fixed:

- latest date by which the EN has to be implemented
at national level by publication of an identical
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- latest date by which the national standards conflicting
with the EN have to be withdrawn (dow) 2005-05-01

This European Standard shall be used in conjunction with EN 61207-1.

Annexes designated "normative" are part of the body of the standard.

Annexes designated "informative" are given for information only.

In this standard, annex ZA is normative and annexes A and B are informative.

Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 61207-3:2002 was approved by CENELEC as a European Standard without any modification.

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INTRODUCTION

Paramagnetic oxygen analyzers respond to partial pressure and not volumetric concentration. They are used in a wide range of industrial, laboratory and other applications where the rated measuring range of the analyzer is between 0 % to 1 % and 0 % to 100 %, at reference pressure.

Only a few gases display paramagnetism (for example, oxygen, nitric oxide and nitrogen dioxide). Oxygen has a particularly strong paramagnetic susceptibility (see annex A). By employing this particular property of oxygen, analyzers have been designed which can be highly specific to the measurement in most industrial applications, where, for example, high background levels of hydrocarbons may be present.

There are several different techniques described for measuring the paramagnetic properties of oxygen, but three main methods have evolved over many years of commercial application.

The three methods are:

- automatic null balance;
- thermomagnetic or magnetic wind;
- differential pressure or Quincke.

These methods all require the sample gas to be clean and dry, though some versions work at elevated temperatures so that samples that are likely to condense at a lower temperature can be analyzed.

Because of this requirement, analyzers often require a sample system to condition the sample prior to measurement.

GAS ANALYZERS – EXPRESSION OF PERFORMANCE –

Part 3: Paramagnetic oxygen analyzers

1 Scope and object

This part of IEC 61207 applies to the three main methods outlined in the introduction. It considers essential ancillary units and applies to analyzers installed indoors and outdoors.

NOTE Safety critical applications can require an additional requirement of system and analyzer specifications not covered in this standard.

This standard is intended

- to specify terminology and definitions related to the functional performance of paramagnetic gas analyzers for the measurement of oxygen in a source gas;
- to unify methods used in making and verifying statements on the functional performance of such analyzers;
- to specify what tests should be performed to determine the functional performance and how such tests should be carried out;
- to provide basic documents to support the application of standards of quality assurance (ISO 9001, ISO 9002 and ISO 9003).

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.

IEC 60654-1:1993, *Industrial-process measurement and control equipment – Operating conditions – Part 1: Climatic conditions*

IEC 61115:1992, *Expression of performance of sample handling systems for process analyzers*

IEC 61207-1:1994, *Expression of performance of gas analyzers – Part 1: General*

ISO 9001:2000, *Quality management systems – Requirements*

ISO 9002:1994, *Quality systems – Model for quality assurance in production, installation and servicing*

ISO 9003:1994, *Quality systems – Model for quality assurance in final inspection and test*

3 Definitions

For the purposes of this part of IEC 61270, the following definitions apply.

3.1

magnetic susceptibility

measure (X) of the variation of the intensity of a magnetic field H , existing in a vacuum, when the vacuum is substituted (filled) by the test substance

$$X = \frac{H^1 - H}{H} \quad (1)$$

where

H is the magnetic field intensity in vacuum;

H^1 is the magnetic field intensity in the test substance.

3.1.1

paramagnetism

substances causing an increase of the magnetic field intensity ($X > 0$)

3.1.2

diamagnetism

substances causing a diminution of the magnetic field intensity ($X < 0$ because $H^1 < H$)

3.1.3

specific magnetic susceptibility

ratio of magnetic susceptibility as follows:

$$X_s = \frac{X}{D} \quad (2)$$

where

D is the density of the considered substance, expressed in $\text{g} \cdot \text{cm}^{-3}$ at 273,15 K (0 °C) and 101,3 kPa (= 1 bar).

The measuring unit of X_s is therefore $\text{cm}^3 \cdot \text{g}^{-1}$.

3.1.4

molar magnetic susceptibility

the molar magnetic susceptibility X_m is the specific magnetic susceptibility multiplied by the molecular weight of the substance considered:

$$X_m = X_s \cdot M \quad (3)$$

where

M is expressed in grammes per mole ($\text{g} \cdot \text{mol}^{-1}$) (for oxygen $M = 32$).

The measuring unit of X_m is therefore $\text{cm}^3 \cdot \text{g}^{-1} \cdot \text{g} \cdot \text{mol}^{-1} = \text{cm}^3 \cdot \text{mol}^{-1}$.

NOTE 1 Electrons determine the magnetic properties of matter in two ways:

- an electron can be considered as a small sphere of negative charge spinning on its axis. This spinning charge produces a magnetic moment;
- an electron travelling in an orbit around a nucleus will also produce a magnetic moment.

It is the combination of the spin moment and the orbital moment that governs the resulting magnetic properties of an individual atom or ion.

In paramagnetic materials, the main contribution to the magnetic moment comes from unpaired electrons. It is the configuration of the orbital electrons and their spin orientations that establish the paramagnetism of the oxygen molecule and distinguish it from most other gases.

NOTE 2 When paramagnetic gases are placed within an external magnetic field, the flux within the gas is higher than it would be in a vacuum, thus paramagnetic gases are attracted to the part of the magnetic field with the strongest magnetic flux. On the contrary, diamagnetic substances contain magnetic dipoles which cancel out some lines of force from the external field; thus diamagnetic gases are subject to repulsion by the magnetic flux.

NOTE 3 The molar magnetic susceptibility of oxygen is inversely proportional to the absolute temperature T according to

$$X_m = (1010557/T) \times 10^{-6} \cdot \text{cm}^3 \cdot \text{mol}^{-1}.$$

(only for oxygen).

NOTE 4 A full understanding of paramagnetism and diamagnetism can be obtained from physics and inorganic chemistry textbooks. The explanation in this standard is to give the user of paramagnetic oxygen analyzers a simple understanding of the physical property utilized.

3.2

automatic null balance analyzer

this type of analyzer uses, as a general principle of operation, the displacement of a body containing a vacuum or a diamagnetic gas, from a region of high magnetic field by paramagnetic oxygen molecules (see figure 1).

The measuring cell typically employs a glass dumb-bell, with the spheres containing nitrogen, suspended on a torsion strip between magnetic pole pieces that concentrate the flux around the dumb-bell. The measuring cell has to be placed in a magnetic circuit. The dumb-bell is then deflected when oxygen molecules enter the measuring cell, a force being exerted on the dumb-bell by the oxygen molecules which are attracted to the strongest part of the magnetic field. By use of optical levers, a feed-back coil, and suitable electronics, an output that is directly proportional to the partial pressure of oxygen can be achieved. The transducer is usually maintained at a constant temperature to prevent the variations in magnetic susceptibility with temperature from introducing errors. Additionally, the elevated temperature helps in applications where the sample is not particularly dry. Some analyzers are designed so that the transducer operates at a temperature in excess of 373,15 K (100 °C) to further facilitate applications where condensates would form at lower temperature.

3.3

thermomagnetic (magnetic-wind) analyzers

this type of analyzer utilizes the temperature dependence of the magnetic susceptibility to generate a magnetically induced gas flow which can then be measured by a flow sensor. The sample gas passes into a chamber designed in such a way that the inlet splits the flow (see figure 2).

The two flows recombine at the outlet. A connecting tube is placed centrally with the flow sensor wound on it. Half of the connecting tube is placed between the poles of a strong magnet. The flow sensor is effectively two coils of wire heated to about 353,15 K (80 °C) by passage of a current. The cold oxygen molecules are diverted by the magnetic field into the central tube, and, as they heat up, their magnetic susceptibility is reduced and more cold oxygen molecules enter the connecting tube. A flow of oxygen is generated in this way through the transversal connecting tube, with the effect of cooling the first coil (which is placed in the magnetic field area), while the temperature of the second coil is not essentially influenced by this transversal flow. Since the two coils are wound with thermosensitive wire (for example, platinum wire) and connected together to build a Wheatstone bridge, the resulting unbalance current is a nearly proportional function of the oxygen partial pressure in the test gas.

More recent analyzers use more refined measuring cells, torodial shaped resistors instead of the two-coil flow sensor and employ temperature control to minimize ambient temperature changes.

As this method relies on heat transfer, the thermal conductivity of background gases will affect the oxygen reading and the composition of the background has to be known. Some analyzers can give a first-order correction for this by utilizing further compensation devices.

Thermomagnetic analyzers do not produce a strictly linear output, and additional signal processing is required to linearize the output.

3.4

differential pressure (Quincke) analyzers

this type of analyzer utilizes a pneumatic balance system established by using a reference gas (such as nitrogen). The measuring cell is designed so that at the reference gas inlet the flow is divided into two paths. These flows recombine at the reference gas outlet, where the sample is also introduced. A differential pressure sensor (or microflow sensor) is positioned across the two reference gas flows so that any imbalance is detected. A magnet is situated in the vicinity of the reference gas outlet in one arm of the measuring cell so that oxygen in the sample is attracted into the arm, thereby causing a back pressure which is detected by the pressure sensor (see figure 3).

Differential pressure analyzers are independent of thermal conductivity of background gases, and as only the reference gas comes in contact with the sensor, corrosion problems are minimal. Some instruments use pulsed magnetic fields to improve tilt sensitivity, and certain designs compensate for vibration effects.

3.5

hazardous area

area where there is a possibility of release of potentially flammable gases, vapours or dusts. Restrictions in the use of electrical equipment apply in hazardous areas