
Gas analysis — Handling of calibration gases and gas mixtures — Guidelines

*Analyse des gaz — Mise en oeuvre des gaz et des mélanges de gaz
pour étalonnage — Lignes directrices*

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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.

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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For an explanation on 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 the following URL: www.iso.org/iso/foreword.html

This document was prepared by Technical Committee ISO/TC 158, *Analysis of gases*.

This second edition cancels and replaces the first edition (ISO 16664:2004), which has been technically revised. The major changes are the following:

- [Figures 1](#) and [5](#) have been revised to more clearly depict the arrangements;
- several references and terminological entries have been updated.

Introduction

This document uses the terms “calibration gas” for both gas mixtures and pure gases as the limiting case of gas mixtures.

The quality of calibration gases in cylinders as certified by producers is defined by

- a) the correct analyte content;
- b) a known uncertainty which is appropriate for its intended use;
- c) the stability;
- d) the homogeneity.

During its utilization period, the quality of calibration gases is influenced by

- storage conditions at the manufacturer’s and user’s sites;
- transport conditions;
- modes of calibration gas withdrawal and transfer;
- the transfer system employed.

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Gas analysis — Handling of calibration gases and gas mixtures — Guidelines

SAFETY PRECAUTIONS — National and international safety regulations concerning storage, use and transportation of pure gases and gas mixtures are to be followed in addition to this document.

1 Scope

This document describes factors that may influence the composition of pure gases and homogeneous gas mixtures used for calibration purposes. This document only applies to gases or gas mixtures that are within the “utilization period”. It provides the following guidelines for the handling and use of calibration gas mixtures:

- storage of calibration gas cylinders;
- calibration gas withdrawal from cylinders;
- transfer of calibration gas from cylinders to the point of calibration.

It also outlines a method of assessing the stability of a gas mixture, taking into account the gas composition uncertainty given on the certificate and the user’s measurement uncertainty.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

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

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

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

3.1

calibration gas

pure gas or gas mixture used for calibration

3.2

calibration gas mixture

gas mixture of known *stability* (3.9) and *homogeneity* (3.4) whose composition is well established for use in the calibration or verification of a measuring instrument or for the validation of a measurement

Note 1 to entry: Calibration gas mixtures are measurement standards (Annex A) as defined in ISO/IEC Guide 99:2007.

[SOURCE: ISO 7504:2015, 5.1]

3.3

component

chemical entity at a defined physical state present in a material or in a mixture

[SOURCE: ISO 7504:2015, 3.3]

3.4

homogeneity

state of a gas mixture wherein all of its components are distributed uniformly throughout the volume occupied by the gas mixture

[SOURCE: ISO 7504:2015, 3.1]

3.5

impurity

undesired minor component present in a parent gas (and thus detectable in a gas mixture made of this parent gas)

[SOURCE: ISO 7504:2015, 5.5]

3.6

leak rate

volume of fluid leaking from the system per unit of time due to incomplete sealing of materials

3.7

leak tightness

conformity to a specified leak rate

3.8

step response time

duration between the instant when an input quantity value of a measuring instrument or measuring system is subjected to an abrupt change between two specified constant quantity values and the instant when a corresponding indication settles within specified limits around its final steady value

[SOURCE: ISO/IEC Guide 99:2007]

3.9

stability

attribute of a gas mixture, under specified conditions, to maintain its composition within specified uncertainty limits for a specified period of time (maximum storage life)

[SOURCE: ISO 7504:2015, 3.2]

3.10

maximum storage life

period after which the properties stated for a gas mixture cannot be warranted to lie within their limits

Note 1 to entry: This period is usually identified as that for which the producer ensures that the gas mixture maintains its composition within the specified limits when it is stored in accordance with the requirements based upon the concepts defined in ISO 7504:2015, 7.1 to 7.4.

Note 2 to entry: The end of this period may be indicated by an "expiry date" (see also ISO 6142-1).

[SOURCE: ISO 7504:2015, 7.5]

3.11

transfer system

gas-conducting system which begins at the cylinder valve and ends at the gas sample inlet to the measuring instrument and includes all structural elements

3.12**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 estimated systematic effects are not corrected for but, instead, associated measurement uncertainty components are incorporated.

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

Note 3 to entry: Measurement uncertainty comprises, in general, many components. Some of these may be evaluated by Type A evaluation of measurement uncertainty from the statistical distribution of the quantity values from series of measurements and can be characterized by standard deviations. The other components, which may 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]

3.13**utilization period**

time between the date of certification and the expiry date

3.14**permeability**

property of a material of transmitting gases and liquids by passage through one surface and out at another surface by diffusion and sorption processes

Note 1 to entry: Not to be confused with porosity.

[SOURCE: ISO 472:2013, 2.690]

4 Transport and storage**4.1 General remarks**

After preparation of the calibration gas, the gas cylinder is transported to the user. The environment in which the cylinders are transported is not normally regulated in terms of temperature and humidity. Low temperatures may have a detrimental impact on the mixture composition, especially when condensable components are present in the mixture. As a consequence of this, environmental conditions during transport and storage should never exceed those recommended by the manufacturer.

Gas cylinders and especially cylinder valves shall be free of grease and other lubricants. During storage and transportation, cylinder valves shall be closed, sealing nuts or plugs shall be tightened and suitable protection devices shall be attached, e.g. caps or valve guards.

The gas cylinders are transported in several ways, e.g. by air, railway, road and on water. In some specific cases, the temperature restrictions may be such that not every means of transport is acceptable.

4.2 Low temperature

The gas cylinder may be exposed to low temperatures during storage and transportation. For gas mixtures containing condensable components, it is important that the cylinder is not stored or transported at temperatures below those recommended by the manufacturer. If the mixture is exposed

to temperatures below the stated range, some components may condense and this will change the composition of the mixture.

If the mixture has been exposed to temperatures lower than those recommended by the manufacturer, the certificate from the manufacturer is no longer valid. In this case, it is very important that the mixture shall not be used before the manufacturer is asked for further advice. He may advise homogenizing the mixture before usage.

4.3 High temperature

Avoid high temperatures (heating) close to the cylinder, e.g. from welding flames, blowlamps, ovens or other intensive heat sources. High temperatures will result in higher pressures leading to potentially hazardous situations. In addition, elevated temperatures may result in decomposition of thermally unstable species.

4.4 Water

Gas cylinders shall be protected from excessive humidity during transport. Transportation by boat may result in the cylinder being sprayed with water; this and/or excessive humidity may cause corrosion of the cylinder valve. Always protect the cylinder from precipitation to prevent corrosion. If the cylinders are stored outdoors protected by a roof, the cylinder base should also be protected from water accumulating on the floor by raising it above the ground.

4.5 Storage and handling

The best way to store calibration gas mixtures for a longer period is by laying the cylinders in a horizontal position, well protected against rolling and falling. For safety reasons, it is necessary to separate cylinders containing flammable gases from cylinders containing oxidizing components.

WARNING — For general safety reasons, never heat cylinders above the maximum temperature specified by the manufacturer.

Mixtures containing condensable components may require rehomogenization if stored for longer periods of time and if exposure to temperatures below the condensation point cannot be excluded. This may be done by bringing up the cylinders to ambient temperature and rotating them into a horizontal position for an appropriate period of time, which may depend on the matrix gas and the components (see 5.2).

After rehomogenization, it is necessary to contact the manufacturer in order to verify the validity of the calibration gas.

5 Mode of withdrawal

5.1 General

In the withdrawal of the gas from the cylinder through the transfer system, a number of aspects shall be considered.

5.2 Minimum utilization pressure

The information attached to the cylinder indicates, if applicable, a pressure value below which the gas should not be used. It has been reported that in some cases under a certain pressure, gas molecules that were attached to the cylinder wall come off this cylinder wall when the cylinder pressure drops, resulting in a higher mole fraction.

In addition to this effect on the stability of the gas mixture, it is important from the point of view of the manufacturer that a cylinder is not completely emptied, as the cylinder could then be contaminated with environmental air. This especially applies to specially treated cylinders where stability is an issue.

5.3 Temperature

Gas mixtures containing condensable components are often limited to a certain temperature range by the manufacturer. In calculating such a mixture, the manufacturer will assume a certain temperature of usage to calculate the vapour pressure at that specific temperature. Normally, a safety tolerance is included to allow use of the mixture within a certain temperature range; however, outside this range the condensable component may condensate, resulting in a change of gas mixture composition. In analysing gas mixtures, it is recommended to allow all cylinders to reach temperature equilibrium. Differences in temperature of different gas mixtures will influence the response of the gas analyser to these mixtures, according to the gas law (Boyle, Gay-Lussac).

5.4 Pressure reduction and flow

Normally, the withdrawal of gas from a cylinder is regulated by a pressure reducer and/or flow controller (needle valve, mass-flow controller, capillary, etc.). Due to the reversible adiabatic expansion of the gas when withdrawing the gas from the cylinder, cooling of the gas in the cylinder will occur. Furthermore, Joule Thomson cooling and/or heating will change the temperature of the transported gas itself. Again, especially with mixtures containing condensable components, condensation might occur due to these temperature effects. It is important that the pressure drop across flow controllers is minimized. Flow characteristics of flow controllers are normally specified by the manufacturer and give sufficient information to judge whether the requested flow can be controlled by the chosen flow controllers. In calculating the pressure drop, tube sizing (inside diameter and length) shall also be considered.

External heating of the gas at or before the reducer and using more than one reducer to drop the pressure in stages could help to minimize the danger of condensation.

5.5 Replacement, change of cylinder positions

Re-connecting cylinders may result in leaking connections. This shall be avoided by completing leak testing. In an optimum set-up, the reducer should remain on the cylinder and the cylinder is preferably left with some gas inside. This will help to reduce the number of purge cycles to flush the reducer prior to analysis. Even in this optimum set-up, some environmental air diffusion into the reducer over time may occur, even if this is pressurized.

NOTE In the long run, there will usually be some diffusion from O₂ and H₂O from the environment into the reducing valve, even if this is pressurized.

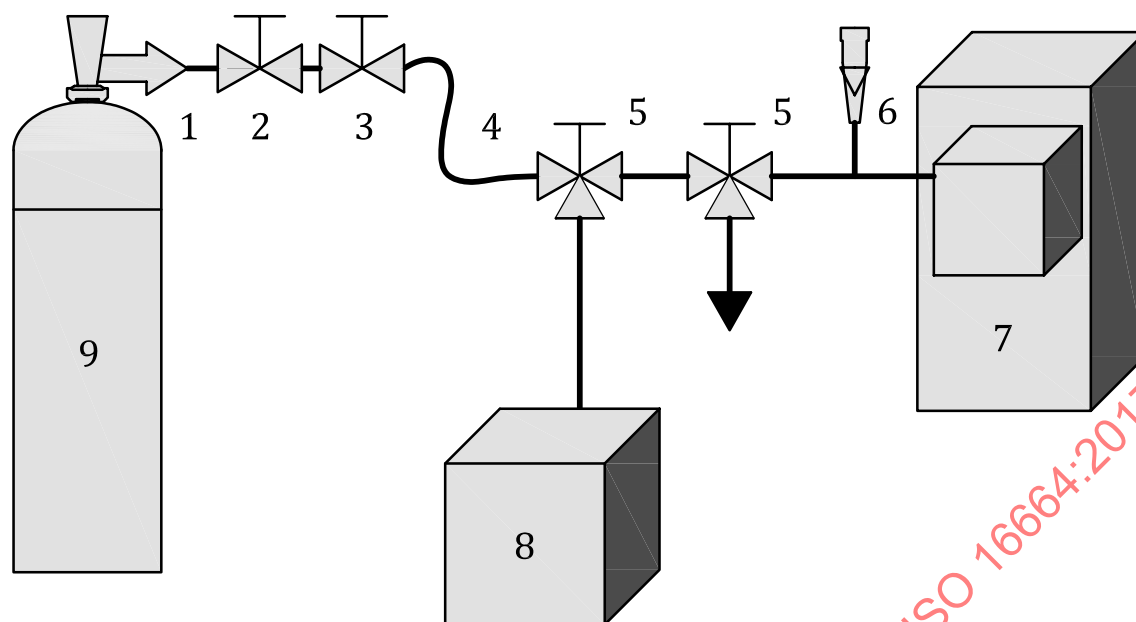
6 Transfer system

6.1 Purging procedure

The transfer-line integrity, including the leak tightness and cleanliness of all the components (pressure regulator, valves, transfer line, connections, etc.) shall be guaranteed. In order to guarantee this, an appropriate purging procedure shall be used. There are several simple methods that may be used to purge the transfer system; the most effective method uses a vacuum pump. In any case, it is important to open the cylinder valve only partially and only for a very short time (i.e. 0,5 s), both for safety reasons and in order to avoid back contamination.

If a vacuum pump is available, then the purging procedure should be as follows (see also [Figure 1](#)).

Sequentially evacuate and pressurize the entire transfer line with the gas mixture to be used. This procedure should be repeated several times; typically, three cycles are sufficient. Make sure that pressure regulators are suited for evacuation and that the purging cycle starts with evacuation.



Key

- 1 pressure regulator with purge valve
- 2 dose valve
- 3 shut-off valve
- 4 transfer line
- 5 three-way valve
- 6 excess-flow line with flow indicator (applicable only for extractive monitors)
- 7 motor with sample pump
- 8 vacuum pump
- 9 gas mixture

Figure 1 — Arrangement for a periodic purging procedure for monitor systems

If a vacuum pump is not available, the following procedure is recommended.

Sequentially pressurize and vent the transfer system with the gas mixture to be used. This method is not as effective as the vacuum method, hence more cycles, typically five to eight, are required. The number of cycles depends on the concentration of the measurand; low-concentration mixtures require more steps. However, this method is prone to back contamination and should not be used for oxygen-sensitive mixtures; for these mixtures, the evacuation method is strongly recommended.

For both methods, the insertion of a stop valve after the pressure regulator is recommended for safety reasons.

6.2 Considerations when designing and constructing gas transfer lines

6.2.1 Modes of gas sampling

The design of the gas transfer line is dependent on the sample introduction method used by the analyser. Typically, there are two methods of sample introduction.

- a) Extractive analysers use a sample pump to move the calibration and zero gases from the sampling point to the point of analysis. The sample pump may be located upstream of the analyser and in this mode the gas is forced into the analyser. Conversely, the sample pump may also be located downstream of the analyser and in this mode the gas is forced through the analyser. In both cases, the transfer system shall include an excess-flow line to prevent over-pressurising the

analyser and sample pump. The excess-flow line shall be located at the end of the transfer line and before the analyser in a “T” orientation (see [Figure 1](#)). The length of the excess-flow line shall be sufficient to prevent ambient air from the laboratory being pumped into the analyser when valve switching occurs during normal instrument operation (a typical length for an excess-flow line is approximately 1 m). It is also pertinent to use a flow indicator on the output of the excess-flow line to indicate that excess flow is occurring. Calibrations and analyses, performed using extractive analysers without excess flow through this line, are invalid.

- b) Non-extractive analysers rely on pressure from gas cylinders to cause the gas to flow through the transfer line and analyser, and hence do not require an excess-flow line. However, many analysers, especially optical instruments, are sensitive to gas pressure and gas flow; it is therefore important to ensure the sample and calibration gases are introduced into the analyser under identical conditions.

6.2.2 Pressure- and flow-reducing equipment

It is important to use the most appropriate pressure- and flow-reduction equipment for a particular requirement. In general terms, this means the equipment needs to be fit for a purpose. The equipment should regulate to the required pressure and flow and should be constructed of the most appropriate material for the gas used. In many cases, the integrity of high quality and expensive calibration gas has been compromised through the use of poor quality or inappropriate pressure- and flow-reduction equipment.

Reactive gases, for example, require extensive purging of the “wetted” areas of the transfer line and, in particular, the pressure regulator. The use of “low-volume” regulators reduces the wetted surface area and hence reduces the level of purging required. For non-reactive gases, such as CO₂ and inert gases, most types of regulators may be used; however, care shall be taken with respect to material compatibility. [Table 1](#) outlines some details covering gas/material compatibilities when considering selection of pressure- and flow-reducing equipment. As this chart is rather general, it is advised to further check the suitability of the transfer system.

NOTE Additional information on material compatibility is found in References [\[9\]](#) and [\[13\]](#).

6.2.3 Material for the construction of transfer lines

As mentioned in [6.2.2](#), the choice of material for the construction of pressure-reducing equipment is extremely important, especially when considering the measurement of more reactive gases. In addition to this, the choice of transfer-line material is also important. [Table 1](#) outlines the most commonly used gases and their level of compatibility with a range of materials.

When using polymeric transfer lines, it is also important to consider their permeability by certain gases and water vapour. For example, PTFE is very inert and suitable for a large range of gases; however, the permeability of this material makes it unsuitable for use with water-soluble gases, as water vapour can easily permeate into the transfer line.

It is also strongly recommended not to use polymeric or rubber-based material of unknown origin in the construction of transfer lines.

Table 1 — Material compatibility

Gas	Material																							
	Stainless steel				Copper/brass				Hastelloy ^f / monel ^g / nickel				Aluminium				Polytetrafluor-ethene				Polyether ether-ketone			
	b	c	d		b	c	d		b	c	d		b	c	d		b	c	d		b	c	d	
inert gas	+	+	+		+	+	+		+	+	+		+	+	+		+	+	+		+	+	+	
O ₂	+	+	+		+	+	+		+	+	+		+	+	+		+	+	+		+	+	+	
CO ₂	+	+	+		+	+	+		+	+	+		+	+	+		+	+	+		+	+	+	
CO	0	+	+		+	+	+		+	+	+		+	+	+		+	+	+		+	+	+	
alkanes	+	+	+		+	+	+		+	+	+		+	+	+		+	+	+		+	+	+	
alkenes	+	+	+		+	+	+		+	+	+		+	+	+		+	+	+		+	+	+	
aromatics	+	+	+		+	+	+		+	+	+		+	+	+		+	+	+		+	+	+	
NO	+	+	+		+	+	+		+	+	+		+	+	+		+	+	+		+	+	+	
NO ₂	+	+	+		+	+	+		+	+	+		+	+	+		+	+	+		+	+	+	
Cl ₂	0	0	0		+	+	+		+	+	+		+	+	+		+	+	+		+	+	+	
HCl	0**	0**	0**		0	0	0		+	+	+		+	+	+		+	+	+		+	+	+	
NH ₃	+	+	+		+	+	+		+	+	+		+	+	+		+	+	+		+	+	+	
H ₂ S	+	+	+		+	+	+		+	+	+		+	+	+		+	+	+		+	+	+	
SO ₂	+	+	+		+	+	+		+	+	+		+	+	+		+	+	+		+	+	+	

Table 1 (continued)

Gas	Material																													
	Stainless steel			Copper/brass			Hastelloy ^f / monel ^g / nickel			Aluminium			Polytetrafluor-ethene			Polyether ether-ketone			Polyether ether-ketone silica-lined			Glass/quartz			Fluorinated-ethene-propene			Silica-lined stainless steel		
	b	c	d	b	c	d	b	c	d	b	c	d	b	c	d	b	c	d	b	c	d	b	c	d	b	c	d	b	c	d
a	See 6.2.3 for further recommendations.																													
b	Mole fraction, > 1 %.																													
c	Mole fraction, ≥ 0,001 % ≤ 1 %.																													
d	Mole fraction < 0,001 %.																													
e	Symbols are as follows: + = suitable; o = of limited suitability; – = not suitable; * = not suitable for helium; ** = suitable only after passivation; *** = no experience available; usage not recommended for safety reasons.																													
f	Hastelloy is an example of a suitable product available commercially. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of this product.																													
g	Monel is an example of a suitable product available commercially. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of this product.																													

6.2.4 General methods and examples of sampling systems

For continuous gas analysers, two flow charts are presented giving examples of procedures to test the integrity of the sampling system.

The first flow chart (given in [Figure 2](#)) explains a simple procedure to check the selected transfer system through the repeatability of the analyser readings.

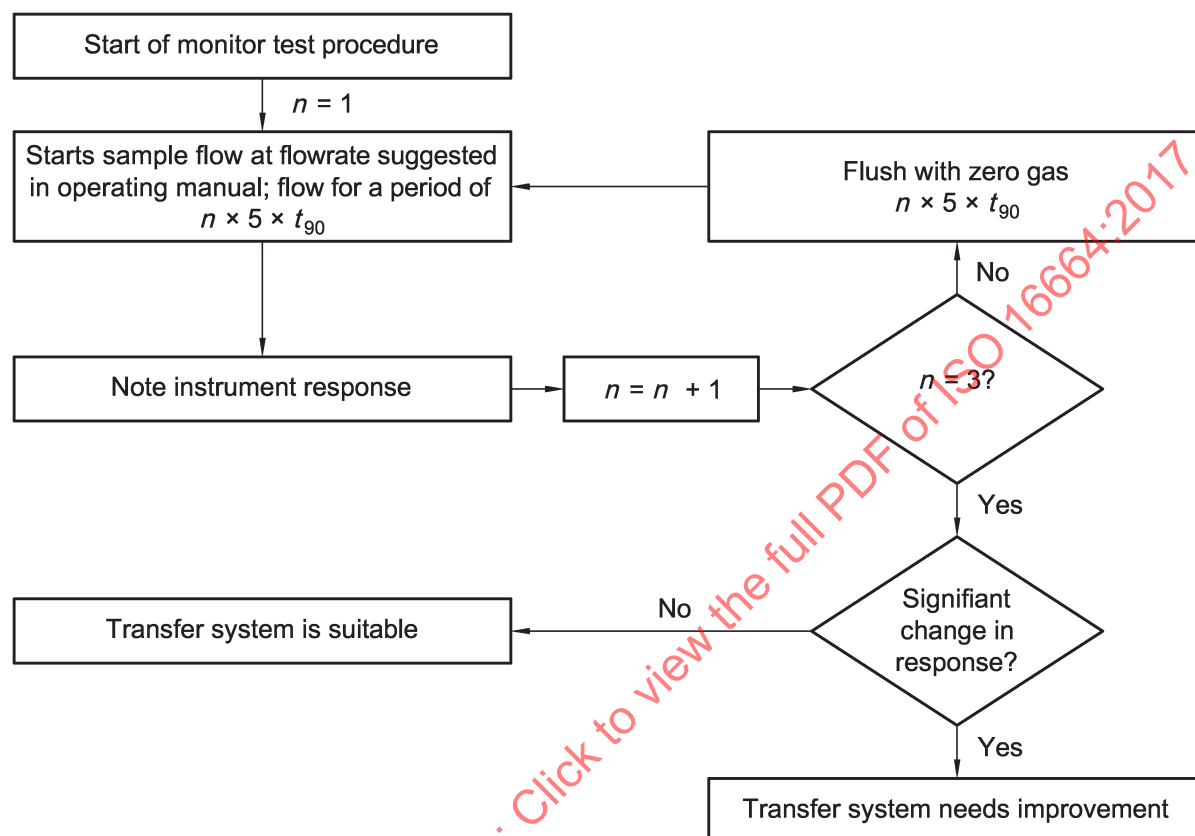
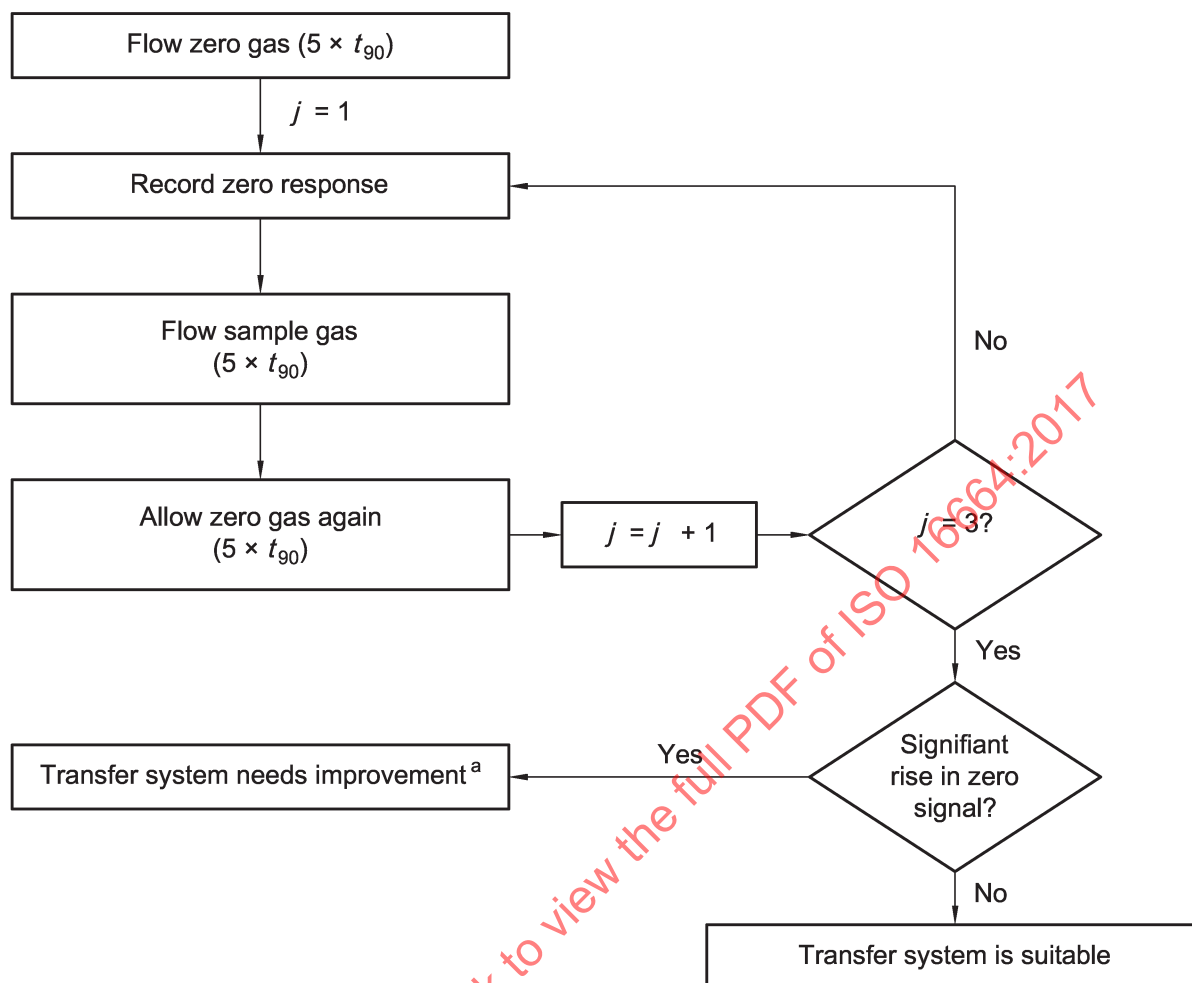


Figure 2 — Flow chart of the test procedure for suitability of transfer system for continuous gas analysers

The second flow chart ([Figure 3](#)) explains a procedure to test the transfer system for memory effects.

In both procedures, it is helpful to attach a chart recorder or other data recording device to the output signal.



- ^a When the outcome of this test shows that the transfer system needs improvement, double the flow and/or heat the transfer lines and repeat the procedure.

Figure 3 — Flow chart of the check on memory effects in the transfer systems

The typical response time t_{90} is normally specified in the operating manual and may be defined as the time between the introduction of the gas and the time that 90 % of the concentration change is displayed on the monitor.

The judgement whether a change in response is significant depends on the aimed accuracy; the change in response should be greater than the specified zero and span drift.

The third flow chart (Figure 4) presents an effective method to check the suitability of the transfer system for a GC application (see Figure 5). The check for any leaks by controlling the presence of oxygen is only applicable with an oxygen-sensitive detector [e.g. gas chromatograph/thermal conductivity detector (GC/TCD), gas chromatograph/discharge ionization detector (GC/DID) or gas chromatograph/mass spectrometer (GC-MS)]. In this method, the sample flow varies from the target flow down to 1/4 of this flow.

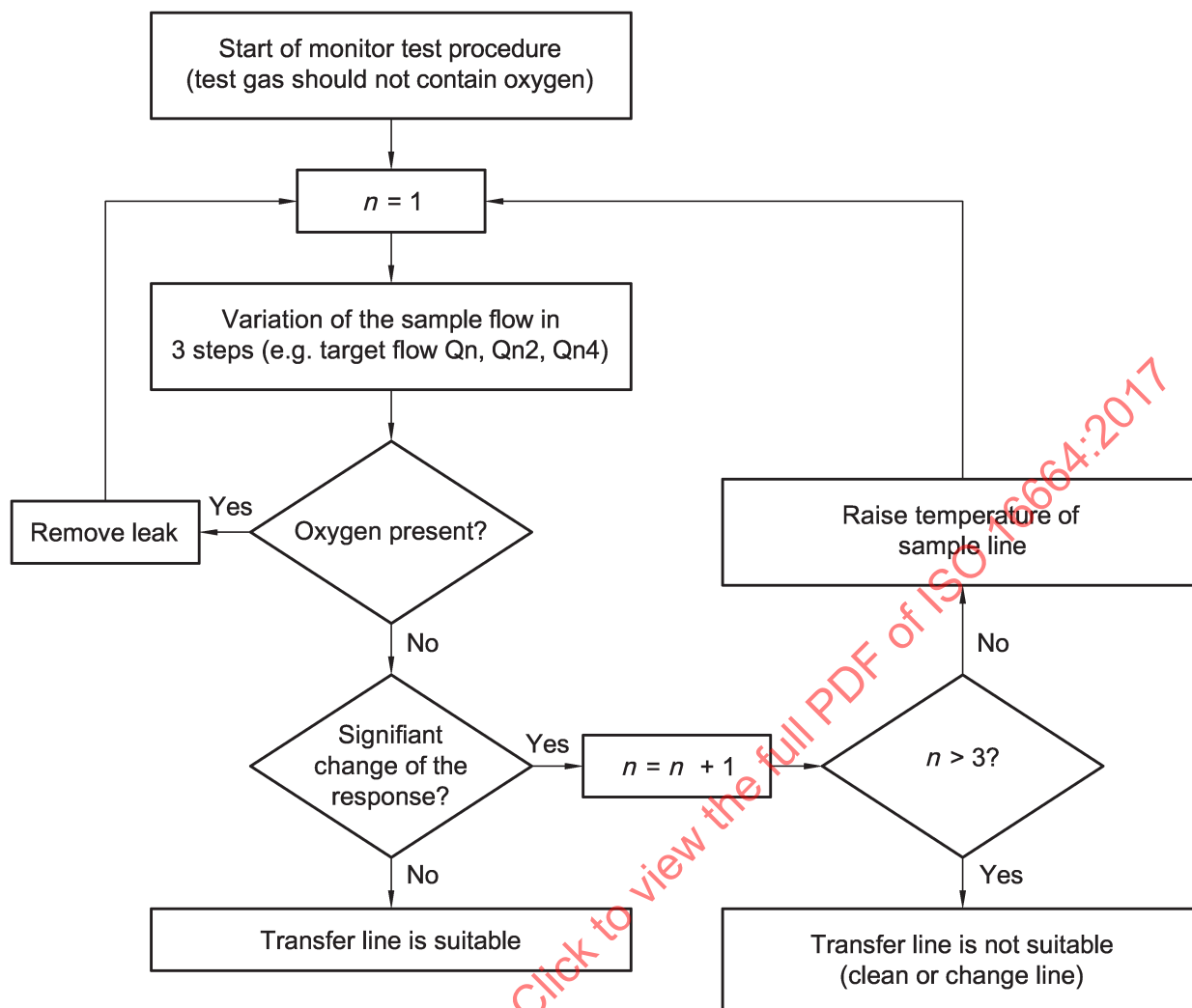
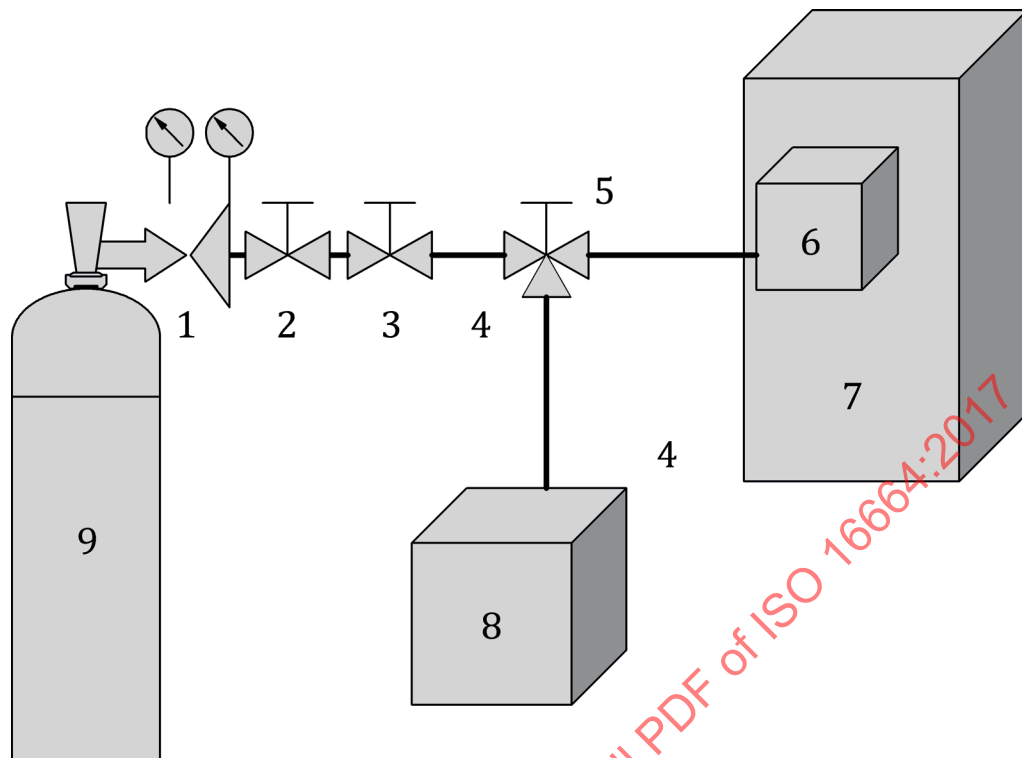


Figure 4 — Flow chart of the suitability test procedure for a transfer system for GCs with an oxygen-sensitive detector

**Key**

- 1 pressure regulator with purge valve
- 2 dose valve
- 3 shut-off valve
- 4 transfer line
- 5 three-way valve
- 6 gas sample inlet system
- 7 gas chromatograph
- 8 vacuum pump
- 9 gas mixture

Figure 5 — Arrangement for a periodic purging procedure with a GC

7 Stability

The previous clauses discuss all precautions to be taken by the user of the gas mixtures to ensure that the integrity of the gas mixture as supplied by the manufacturer is not compromised during use. However, sometimes unexpected influences do interfere and the continuing stability of the mixture should be demonstrated. A possible method to check the stability of calibration gases is given in [Annex A](#).