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# Gas cylinders — Gases and gas mixtures — Determination of fire potential and oxidizing ability for the selection of cylinder valve outlets

*Bouteilles à gaz — Gaz et mélanges de gaz — Détermination du potentiel d'inflammabilité et d'oxydation pour le choix des raccords de sortie de robinets*



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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 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 58, *Gas cylinders*, Subcommittee SC 2, *Cylinder fittings*.



This fourth edition cancels and replaces the third edition (ISO 10156:2010), which has been technically revised. It also incorporates ISO 10156:2010/Cor 1:2010.

The main changes compared to the previous edition are as follows:

— 4.1, 4.2.5 and 4.4 have been technically revised;

— 4.5 and 4.6 have been added.

# Introduction

ISO 5145 specifies the dimensions of different cylinder valve outlets for different compatible gas groups. These compatible gas groups are determined according to practical criteria defined in ISO 14456.

These criteria are based on certain physical, chemical, toxic and corrosive properties of the gases. In particular, the flammability in air and the oxidizing ability are considered in this document.

One of the potential complications that prompted the development of this document is that while there are abundant data in the literature relating to pure gases, differences can be found, depending upon the test methods employed. In the case of gas mixtures, data in the literature are often incomplete or even non-existent.

The initial aim of this document was to eliminate the ambiguities in the case of differences in the literature, and above all, to supplement existing data (mainly in the case of gas mixtures).

Subsequently, this document was used for other purposes than the selection of cylinder valve outlets, such as establishing flammability and oxidizing potential data for the classification and labelling of gases and gas mixtures.

This document is intended to be used under a variety of national regulatory regimes, but has been written so that it is suitable for the application of the UN Model Regulations and the UN-GHS[9].

# Gas cylinders — Gases and gas mixtures — Determination of fire potential and oxidizing ability for the selection of cylinder valve outlets

## 1 Scope

This document specifies methods for determining whether or not a gas or gas mixture is flammable in air and whether a gas or gas mixture is more or less oxidizing than air under atmospheric conditions.

This document is intended to be used for the classification of gases and gas mixtures including the selection of gas cylinder valve outlets.

This document does not cover the safe preparation of these mixtures under pressure and at temperatures other than ambient.

## 2 Normative references

There are no normative references in this document.



## 3 Terms, definitions, symbols and units

### 3.1 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

**3.1.1**
**gas or gas mixture flammable in air**
gas or gas mixture that is ignitable in air at atmospheric pressure and a temperature of 20 °C

**3.1.2**
**lower flammability limit in air**
minimum content of a gas or gas mixture in a homogeneous mixture with air at which a flame just starts to propagate

Note 1 to entry: The lower flammability limit is determined at atmospheric conditions.

Note 2 to entry: The term “flammability limit”, as used in this document, is sometimes called “explosion limit”.

**3.1.3**
**upper flammability limit in air**
maximum content of a gas or gas mixture in a homogeneous mixture with air at which a flame just starts to propagate

Note 1 to entry: The upper flammability limit is determined at atmospheric conditions.

Note 2 to entry: The term “flammability limit”, as used in this document, is sometimes called “explosion limit”.

**3.1.4**
**flammability range**
range of concentration between the lower and upper flammability limits

Note 1 to entry: The term "flammability range", as used in this document, is sometimes also called "explosion range".

**3.1.5**
**gas or gas mixture more oxidizing than air**
gas or gas mixture that is able, at atmospheric pressure, to support the combustion more than a reference mixture consisting of 23,5 % oxygen in nitrogen

**3.1.6**
**oxidizing power**
**OP**
dimensionless number that compares the oxidizing capability of a gas or gas mixture to that of oxygen

Note 1 to entry: OP is calculated as the sum of the products of the mole fraction(s) of each oxidizing component times its coefficient of oxygen equivalency, $C_i$.

**3.1.7**
**atmospheric conditions**
standard pressure of 101,3 kPa at 20 °C

## 3.2 Symbols



$A_i$ molar fraction of the $i^{th}$ flammable gas in a gas mixture, in %

$B_k$ molar fraction of the $k^{th}$ inert gas in a gas mixture, in %

$C_i$ coefficient of oxygen equivalency

$F_i$ $i^{th}$ flammable gas in a gas mixture

$I_k$ $k^{th}$ inert gas in a gas mixture

$n$ number of flammable gases in a gas mixture

$p$ number of inert gases in a gas mixture

$K_k$ coefficient of equivalency of an inert gas relative to nitrogen (see Table 1)

$A_i'$ equivalent content of a flammable gas

$L_i$ lower flammability limit in air of a flammable gas

$T_{ci}$ maximum content of flammable gas which, when mixed with nitrogen, is not flammable in air, in %

$x_i$ molar fraction of the oxidizing component, in %

He helium

Ar argon

Ne neon

Kr krypton

Xe xenon

$N_2$ nitrogen

$H_2$ hydrogen

$O_2$ oxygen

$CO_2$ carbon dioxide

$SO_2$ sulfur dioxide

$N_2O$ nitrous oxide

$SF_6$ sulfur hexafluoride

$CF_4$ carbon tetrafluoride

$C_3F_8$ octafluoropropane

$C_2HF_5$ pentafluoroethane

$CH_4$ methane

### 3.3 Units

For the purposes of this document, all gas percentages (%) are given as molar fractions (mol. %) which are equivalent to volume fractions (vol. %) under normal atmospheric conditions.



## 4 Flammability of gases and gas mixtures in air

### 4.1 General



4.2 and 4.3 give a test method and a calculation method for determining whether a gas or gas mixture is flammable in air. This is used to determine a valve outlet for transportation or GHS classification.

The test method (given in 4.2) may be used in all cases but shall be used when $T_{ci}$ (or $L_i$) values are not available.

The calculation method (given in 4.3) may only be used if reliable $T_{ci}$ (or $L_i$) values are available.

4.5 gives a calculation method to determine the lower flammability limit of the flammable mixture determined in 4.3 and may be used for the GHS flammable gas categories.

In cases where the test result is different from that obtained by calculation, the test result shall take precedence.

The non-flammable mixtures defined by UN number shall overrule any classification done by calculation.

### 4.2 Test method

#### 4.2.1 Key points concerning safety

Tests shall be carried out by trained and competent personnel working in accordance with authorized procedures (see also 4.2.4). The reaction tube and flowmeter shall be adequately screened to protect personnel in the event of an explosion. Personnel shall wear personal protective equipment including safety glasses. During the ignition sequence, the reaction tube shall be open to the atmosphere and isolated from the gas supply. Care shall also be taken during the analysis of the test gas or mixture.

#### 4.2.2 Principle

The gas or gas mixture is mixed in the desired proportions with air. In the quiescent test mixture, an ignition is initiated using an electric spark and it is observed whether or not a flame propagates through the reaction tube.

### 4.2.3 Test apparatus and materials

#### 4.2.3.1 General

The apparatus (see Figure 1) includes:

— a mixer;

— a tube in which the reaction takes place;

— an ignition system;

— a system of analysis to determine the test gas composition.

NOTE Alternative equivalent apparatus can be used, as described in standard test methods for the determination of flammability limits, e.g. EN 1839 and ASTM E681.

#### 4.2.3.2 Preparation

#### 4.2.3.2.1 Test gas



The test gas shall be prepared to represent the most flammable composition that can occur in the normal course of production. The criteria to be used in establishing the composition of the test gas are manufacturing tolerances, i.e. the test gas shall contain the highest concentration of flammable gases encountered in the normal manufacturing process and the moisture content shall be less than or equal to 0,01 %. The test gas shall be thoroughly mixed and carefully analysed to determine the exact composition.

#### 4.2.3.2.2 Compressed air

The compressed air shall be analysed and the moisture content shall be less than or equal to 0,01 %.

#### 4.2.3.2.3 Test gas/air mixture

The compressed air and the gas to be tested are mixed in a blender, controlling the flowrates. The air-flammable gas mixture shall be analysed using a chromatograph or a simple oxygen analyser and a flammable gas detector.

#### 4.2.3.3 Reaction tube

The test vessel is an upright cylinder of thick glass (e.g. 5 mm) having a minimum inner diameter of 50 mm and a minimum height of 300 mm. The ignition electrodes are separated by a distance of 5 mm and are placed 50 mm to 60 mm above the bottom of the cylinder. The cylinder is fitted with a pressure-release opening. The apparatus shall be shielded to restrict any explosion damage.

#### 4.2.3.4 Ignition system

A spark generator capable of supplying high voltage sparks (e.g. 15 kV, 30 mA, a.c.) with energy of 10 J shall be used. The spark gap (distance between the electrodes) shall be 5 mm, the spark duration 0,2 s to 0,5 s.

### 4.2.4 Procedure for determination of flammability

When carrying out flammability tests, care shall be taken to avoid explosion. This can be done by commencing the experimental work at a known “safe” concentration of 1 % test gas in air. Subsequently, the initial gas concentration can be increased in small steps by 1 % until ignition occurs.

Prior to each ignition attempt, the test vessel shall be purged with the test mixture. The purging volume shall be at least 10 times the volume of the test vessel. Then, an ignition is attempted with the induction spark when the test mixture is quiescent, and it is observed visually whether or not a flame detaches from the ignition source and propagates.

If a flame detachment and an upwards propagation of at least 100 mm is observed, the test substance shall be classified as flammable.

If the chemical structure of the gas indicates that it would be non-flammable and the composition of the stoichiometric mixture with air can be calculated, only mixtures in the range from 10 % (absolute) less than the stoichiometric composition to 10 % greater than this composition need to be tested in 1 % steps.

With mixtures containing hydrogen, the flame is almost colourless. In order to confirm the presence of such flames, the use of temperature-measuring probes is recommended [see Figure 1 a)].

### 4.2.5 Procedure for determination of flammability limits

Unlike at the determination of flammability in general, it is necessary to apply a different test procedure for determining flammability limits ($FL$). Using the same test apparatus, test gas preparation and criterion of ignition as described in 4.2.3 and 4.2.4, the characterization of flammability limits consists of determining the amount of test substance in air with which the test mixture no longer ignites. Close to the flammability limit, the incremental change of test substance content in air is selected such that it is almost 0,1 % by volume for $FL < 10$ % and 0,2 % by volume for $FL \geq 10$ %.



For safety reasons, the initial ignition tests are carried out using a test mixture with test substance content which, if possible, lies outside the expected explosion range.

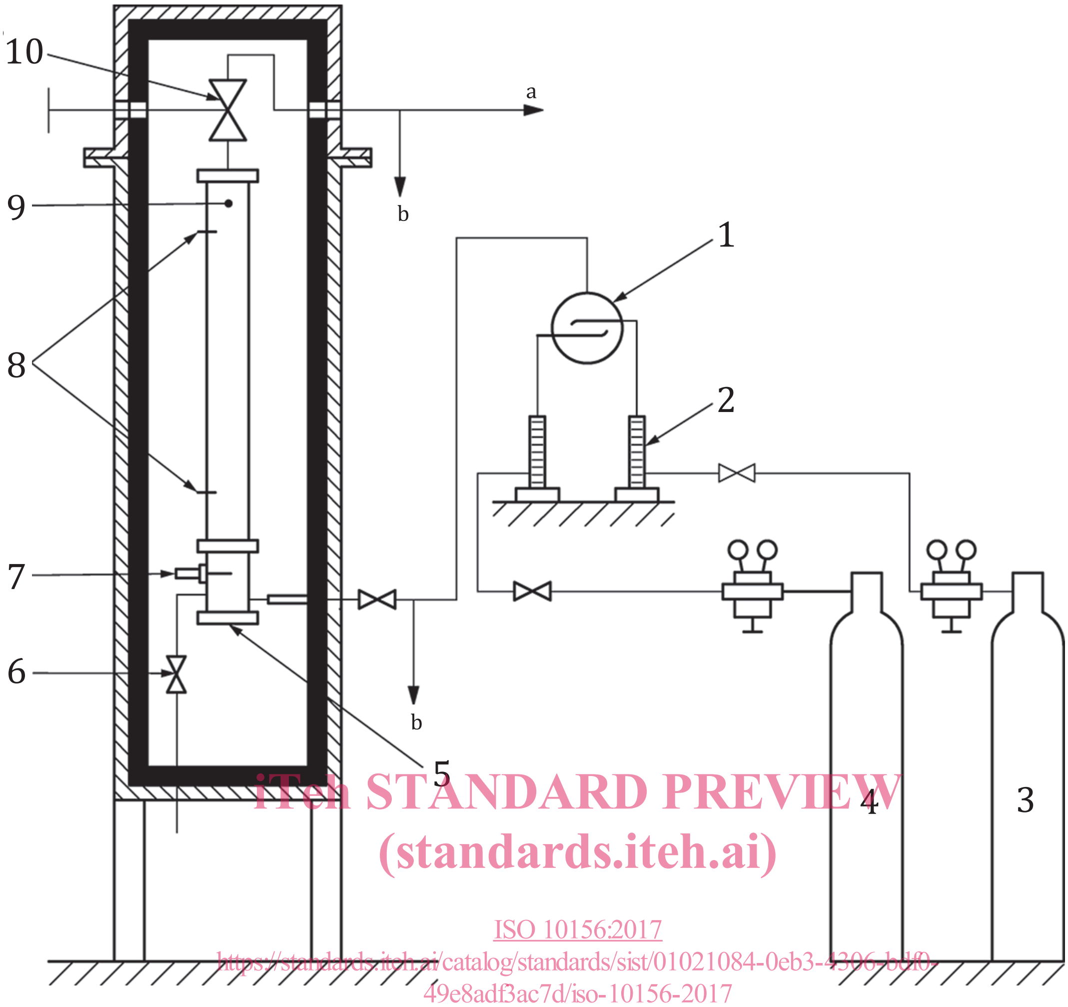
Prior to each ignition attempt, the test vessel is purged with the test mixture. The purging volume shall be at least 10 times the volume of the test vessel. When purging is complete, the inlet to the test vessel is sealed. The test mixture then bypasses the test vessel and flows directly into the exhaust system. An ignition is attempted using the induction spark under quiescent conditions. It is observed whether or not a flame detaches from the ignition source and propagates at least 100 mm.

If an ignition is observed, the test gas content in the test mixture is iteratively varied until no further flame detachment follows. The test mixture concentration at which an ignition just fails (just no flame detachment) shall be confirmed with four additional tests. The determination is terminated when with all five tests a flame detachment is not observed. If flame detachment does occur, the test gas content shall be further changed and the test gas content shall be reduced (lower flammability limit) or to be increased (upper flammability limit) by one increment. Again, the tests are carried out at the new test substance content.

The flammability limit is the test gas concentration in mixture with air at which an ignition just fails.

### 4.2.6 Results for pure gases

A list of flammable gases is given in Table 2 together with $T_{\text{ci}}$ values and $L_i$ values. These values have been obtained using test equipment similar to that described in 4.2.3.






a) Apparatus using Pyrex tube and temperature-measuring probes