INTERNATIONAL STANDARD

ISO 10156

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

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

Reference number
ISO 10156:1990(E)

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.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 10156 was prepared by Technical Committee ISO/TC 58, *Gas cylinders*.

Annex A forms an integral part of this International Standard.

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Introduction

The purpose of ISO 5145 is to establish practical criteria for the determination of outlet connections of gas cylinders of water capacity 150 litres or less. These criteria are based on certain physical and chemical properties of the gases. In particular, the flammability in air and the oxidizing potential (with air as the reference) are considered.

One of the difficulties in the application of ISO 5145 resides in the fact that it is at times difficult to know if a gas or gas mixture is flammable in air or more oxidizing than air.

In fact,

in the case of pure gases, there is abundant data in the literature, although conflicting results are to be found, depending upon the test methods employed;

but, above all,

in the case of gas mixtures, data in the literature is often incomplete or even non-existent.

With standardized test methods, it will be possible

to eliminate the ambiguities in the case of conflicting results in the literature;

and, above all,

to supplement existing data (mainly in the case of gas mixtures).

In particular, the application of standardized test methods will eliminate the ambiguities concerning mixtures in groups 1, 3, 4, 6, 7, 8, 9, 12, 13 and 15, such as they are defined in ISO 5145, since it is necessary to know, in the case of those mixtures, whether or not they are flammable in air and/or more or less oxidizing than air.

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

1 Scope

This International Standard specifies two test methods for determining whether or not a gas is flammable in air and whether a gas is more or less oxidizing than air, respectively, with the aim of eliminating difficulties entailed in the application of ISO 5145.

NOTE 1 For certain special applications, such as special gas mixtures produced to order (in small quantities), it might prove relatively complex to apply the method specified and to perform the special tests necessary to determine the flammability or oxidizing power of the gas mixture.

To avoid these difficulties, a simple method of calculation is recommended to determine rapidly the type of connection to be employed depending upon the characteristics (flammability, oxidizing power, etc.) of the gas mixture and the characteristics of the pure substances making up the mixture.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 4589:1984, *Plastics — Determination of flammability by oxygen index.*

ISO 5145:1990, *Cylinder valve outlets for gases and gas mixtures — Selection and dimensioning.*

3 Definitions and symbols

3.1 Definitions

For the purposes of this International Standard, the following definitions apply:

3.1.1 gas or gas mixture flammable in air: A gas or gas mixture which will ignite in air at atmospheric pressure and a temperature of 20 °C.

3.1.2 lower flammability limit in air: The minimum content of a gas or gas mixture in air at which the gas or gas mixture will ignite. This limit is determined at atmospheric pressure and 20 °C.

3.1.3 gas or gas mixture less oxidizing than air: A gas or gas mixture which is not able, at atmospheric pressure, to support the combustion of substances which are flammable in air.

3.2 Symbols

A_i	molar fraction of a flammable gas in a mixture of gases
B_i	molar fraction of an inert gas in a mixture of gases
C_i	coefficient of oxygen equivalency
F_i	ith flammable gas in a gas mixture
I_i	ith 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_i	coefficient of equivalency of an inert gas relative to nitrogen
A'_i	equivalent content of a flammable gas
N_2	nitrogen

T_{ci}	maximum flammable-gas content for which a mixture of the flammable gas in nitrogen is not flammable in air
H_2	hydrogen
CO_2	carbon dioxide
x_i	minimum concentration of an oxidizing combustion gas, in a mixture with nitrogen, which will support combustion of a test piece
He	helium
Ar	argon
Ne	neon
Kr	krypton
Xe	xenon
SO_2	sulfur dioxide
SF_6	sulfur hexafluoride
CF_4	carbon tetrafluoride
C_3F_8	octafluoropropane
CH_4	methane
N_2O	nitrous oxide
L_i	lower flammability limit in air of a flammable gas
O_2	oxygen

4 Flammability of gases and gas mixtures in air

4.1 General

Gases and gas mixtures which are flammable shall be designated in accordance with ISO 5145:1990, annex A — category I — subdivision 2. Such gases and gas mixtures have flammable limits in air. The following sub-clauses outline a test method and a calculation method for determining whether a gas or gas mixture is flammable. In cases where the test result is different from that obtained by calculation, the test result shall take precedence.

4.2 Test method

4.2.1 Principle

The gas is mixed in the desired proportions with air. Then ignition energy is supplied in the form of an electric arc between two electrodes.

4.2.2 Apparatus and materials

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.

4.2.2.1 Preparation

a) 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 10 ppm by volume. The test gas shall be thoroughly mixed and carefully analysed to determine the exact composition.

b) Compressed air

The compressed air shall be analysed and shown to be free of moisture.

c) Test-gas/air mixture

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

4.2.2.2 Reaction tube

This tube shall be made of thick pyrex glass (e.g. 5 mm), with an inside diameter of at least 50 mm and a length at least five times the diameter.

At one end of the tube, there shall be a cylindrical component designed to take:

— an ignition spark plug, located about 50 mm from the bottom of the tube;

— an inlet for the gas mixture to be tested;

— a relief valve at the bottom of the pyrex tube [see figure 1a)];

— two thermocouples, one located close to the ignition system, the other located close to the top of the tube, the purpose of these thermocouples being to allow easy detection of flame propagation [see figure 1a)] (alternatively, gas ignition may be observed by an experienced operator in a dark room);

— a safety device to minimize the risk of destruction of the tube in the event of an explosion (preferably located close to the ignition system).

The tube and its accessories shall always be very clean in order to avoid any impurities, and particularly moisture resulting from a preceding test or from exposure to the atmosphere, from affecting the determination.

The gas mixture is vented at the top of the reaction tube by a tube fitted with a shut-off valve.

This apparatus is located inside a ventilated metal chamber, one side of which has a window made of high-strength transparent material.

Prior to ignition, the composition of the mixture shall be tested by analysing the gas leaving the reaction tube [see figure 1a), analysis at point 2] to ensure that the tube has been properly purged.

4.2.2.3 Ignition system

A spark generator (e.g. 15 kV) shall be used which can supply sparks (across a 5 mm electrode gap, for instance) with an energy of 10 J per spark.

4.3 Procedure

Care shall be taken when carrying out flammability tests to ensure that the explosive range is avoided. This can be done by commencing the experimental work at “safe” concentrations of flammable gas in air (“safe” = below the expected lower flammable limit). Subsequently, the initial gas concentration can be slowly increased until ignition occurs.

Blend the desired mixture using the flowmeter (the efficiency of this step shall be checked by analysis). Close the gas inlets simultaneously. Just prior to ignition, ensure that the outlet valve (if there is one) is opened, to bring the mixture to atmospheric pressure.

There are several possible results:

a) No combustion: the test-gas mixture is not flammable in air at this concentration. In this case, repeat the test at a slightly higher concentration.

b) Partial combustion: a flame begins to burn around the spark plug, and then goes out. This indicates that the flammability limit is close. In this case, repeat the test at least five times. If, in one of these repeat tests, the flame rises up the tube, it shall be considered that the flammability limit has been reached, i.e. the test gas is flammable.

c) The flame rises slowly up the tube at 10 cm/s to 50 cm/s. In this case, it shall be considered that the limit has been reached, i.e. the test gas is flammable.

d) The flame rises up the tube very rapidly. In this case, the test gas is flammable.

NOTES

2 Instead of flowmeters, other appropriate devices, such as metering pumps, etc., can be used.

3 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 4.2.2.2).

4 Although it is beyond the scope of this International Standard, if a precise value is required for the lower flammability limit of the test gas, then repeated tests must be carried out, varying the flammable-gas content until the threshold point is reached between ignition and no ignition of the flammable gas.

4.4 Key points concerning safety

Tests shall be carried out by trained and competent personnel working in accordance with authorized procedures (see also 4.3). The reaction tube and flowmeter shall be adequately screened to protect the personnel in the event of an explosion. Personnel shall wear 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.

4.5 Results for pure gases

A list of flammable gases is given in annex A together with some lower flammability limits. These values have been obtained using similar test equipment to that described in 4.2.2.

4.6 Calculation method

This method is limited to gas mixtures produced in small quantities in cylinders to indicate if flammable in air.

4.6.1 Mixtures containing n flammable gases and p inert gases

The composition of a mixture of this kind can be expressed as follows:

$$A_1F_1 + \ldots + A_iF_i + \ldots + A_nF_n + B_1I_1 + \ldots + B_iI_i + + \ldots + B_pI_p$$

where

- A_i and B_i are the molar fractions of the ith flammable gas and the ith inert gas, respectively;
- F_i designates the ith flammable gas;
- I_i designates the ith inert gas;
- n is the number of flammable gases;
- p is the number of inert gases.

The composition of the mixture is re-expressed in terms of an equivalent composition in which all the inert-gas fractions are converted into their nitrogen equivalent, using the coefficient of equivalency K_i values given in table 1:

$$A_1F_1 + \ldots + A_iF_i + \ldots + A_nF_n + + (K_1B_1 + \ldots + K_iB_i + \ldots + K_pB_p)N_2$$

Taking the sum of all the component gas fractions to be equal to 1, the expression for the composition becomes:

$$\left(\sum A_iF_i + \sum K_iB_iN_2\right)\left(\frac{1}{\sum A_i + \sum K_iB_i}\right)$$

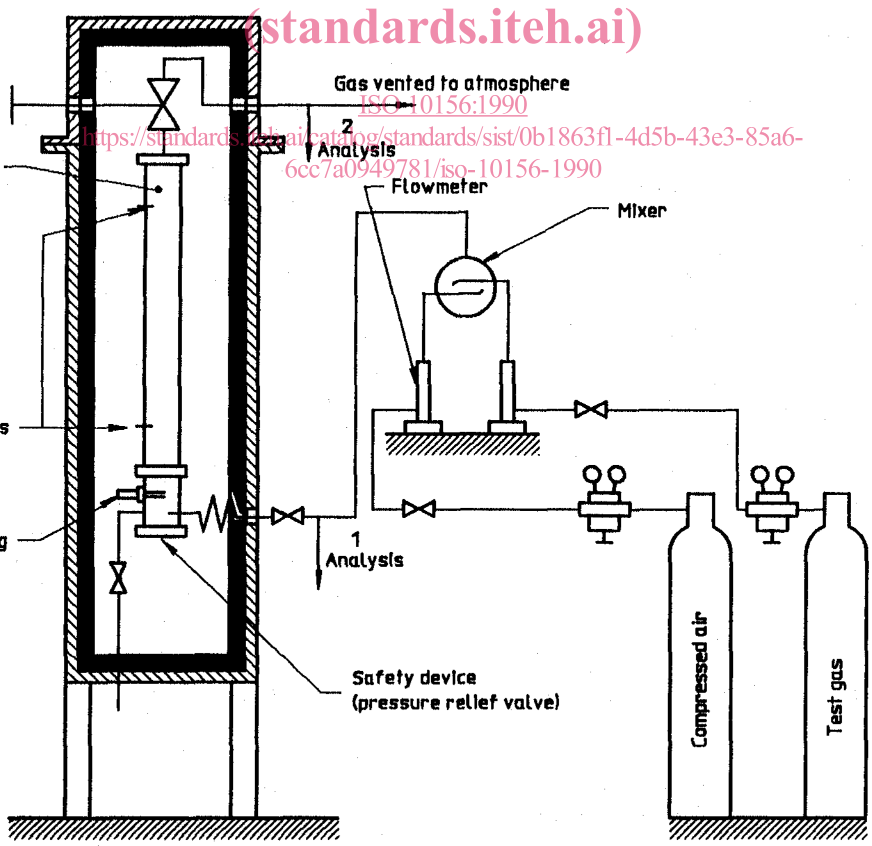
where

$$\frac{A_i}{\sum A_i + \sum K_iB_i} = A'_i$$

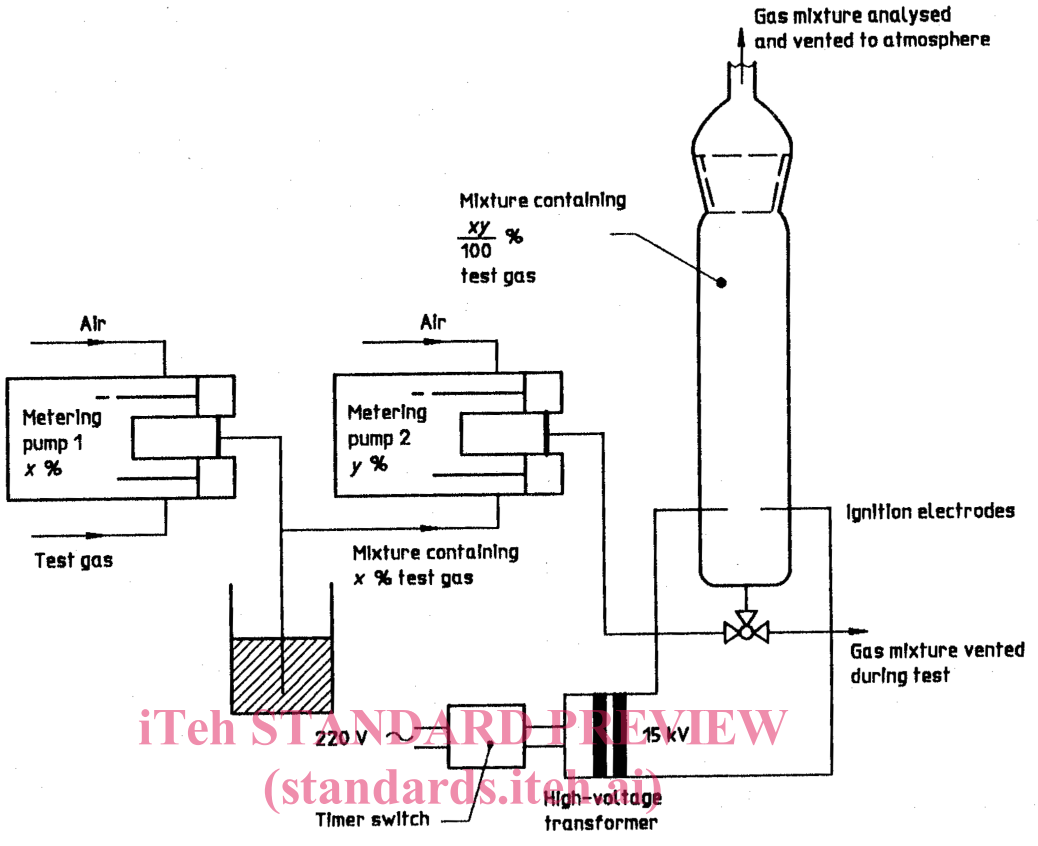
is the equivalent flammable-gas content.

Table 2 gives values for the maximum content T_{ci} of flammable gas which, in a mixture with nitrogen, gives a composition which is not flammable in air. Expressed mathematically, this condition for the mixture not being flammable in air is

$$\sum \frac{A'_i}{T_{ci}} \times 100 \leqslant 1$$



a) Example 1



b) Example 2

Figure 1 — Apparatus for determination of flammability limits of gases at atmospheric pressure and at ambient temperature

Table 1 — Coefficients of equivalency K_i for inert gases relative to nitrogen

Gas	N_2	CO_2	He	Ar	Ne	Kr	Xe	SO_2	SF_6	CF_4	C_3F_8
K_i	1	1,5	0,5	0,5	0,5	0,5	0,5	1,5	1,5	1,5	1,5

NOTES

1 These data are based on experience within the gas industry.

2 The figures are rather conservative estimates, to be sure that they are on the safe side, especially in view of the fact that little data is available in the literature. The data could be updated later when more data are available.

3 For other non-flammable and non-oxidizing gases, containing three atoms or more in their chemical formula, the coefficient of equivalency $K_i = 1{,}5$ shall be used.

Table 2 — Maximum flammable-gas content T_{ci} for which a mixture of the flammable gas in nitrogen is not flammable in air

Gas	T_{ci} [1)] %
Hydrogen	5,7
Carbon monoxide	20
Methane	14,3
Ethane	7,6
Ethylene	6
Butanes	5,7
Propane	6
Propenes	6,5
Butenes	5,5
Isobutene	6
Butadiene	4,5
Acetylene	4
2,2-Dimethylpropane (neopentane, tetramethylmethane)	4
n-Pentane and isopentane	4
n-Hexane	3,5
n-Heptane	2
n-Octane	1,8
Isooctane (2,2,4-trimethylpentane)	1,8
n-Nonane	1,5
n-Decane	1,1
n-Dodecane	1
Cyclopropane	6,8
Cyclohexane	2,5
Benzene	4,2
Toluene	2,1
Methanol	11
Ethanol	5,8
Acetone	4,5
Diethyl ether	3,4
Dimethyl ether	3,7
2,2-Dimethylbutane	2,4
Methylamine	6,8
Methyl formate	7
Methyl acetate	4,3
Ethyl formate	3,9
Methyl acetate	4,3
Methyl ethyl ketone	2
Hydrogen sulfide	5,2
Carbon disulfide	1,5
Fluoromethane	3,7
1,1-Difluoroethylene (R1132a)	6,8
Vinyl bromide	6,8
1-Chloro-1,1-difluoroethane (R142b)	5,5
Vinyl fluoride	3,2
Halocarbon R143a	5,6
1,1-Difluoroethane	4,6
Halocarbon R152a	1
Chloroethane	4,3
Propadiene	2,1
Vinyl methyl ether	2,7
Cyclobutane	2
Methyl-3-butene	1,8
Fluoroethane	4,3
Vinyl chloride	4,5
Cyanogen	7
Arsine	5,6
Diborane	1
Hydrogen cyanide	6,7
Carbonyl sulfide	14
Nickel carbonyl	1,1
Phosphine	1,2
Monoethylamine	4,8
Trimethylamine	2,5
Dimethylamine	3,5
Methylene chloride	10
Methyl mercaptan	4,7
Halocarbon R1113	10
Tetrafluoroethylene	13,7
Bromomethane	16
Ethyl methyl ether	2,5
Lead tetraethyl	2,2
Trifluoroethylene	13,1
Hydrogen selenide	1
Methyl silane	1,4
Silane	1
Monochlorosilane	1
Dichlorosilane	4,5
Germane	1
Ethylene oxide	3,1
Propylene oxide	2,0
Ethylacetylene	1,8
Methylacetylene	1,4

1) When it was impossible to find T_{ci} data, a conservative value was estimated.

EXAMPLE 1

Consider a mixture containing 7 % H_2 + 93 % CO_2.

Using the appropriate K_i value from table 1, this mixture is equivalent to

$$7\ (H_2) + 1{,}5 \times 93\ (N_2)$$

i.e.

$$7\ (H_2) + 139{,}5\ (N_2)$$

or, adjusting the sum of the molar fractions to 1,

$$4{,}78\ \%\ H_2 + 95{,}22\ \%\ N_2.$$

From table 2, it can be seen that the T_{ci} value for H_2 is 5,7.

Since the ratio 4,78/5,7 (= 0,839) is less than 1, the mixture is not flammable in air.

EXAMPLE 2

Consider a mixture comprising 2 % H_2 + 8 % CH_4 + 25 % Ar + 65 % He.

This mixture is equivalent to

$$2\ (H_2) + 8\ (CH_4) + (0{,}5 \times 25 + 0{,}5 \times 65)\ N_2$$

i.e.

$$3{,}63\ \%\ H_2 + 14{,}54\ \%\ CH_4 + 81{,}81\ \%\ N_2.$$

Since the sum

$$\frac{3{,}63}{5{,}7} + \frac{14{,}54}{14{,}3} = 0{,}64 + 1{,}02 = 1{,}66$$

is greater than 1, the mixture is flammable in air.

4.6.2 Mixtures containing one or more flammable gases and one or more oxidizing gases plus one or more inert gases

WARNING — Mixtures containing flammable and oxidizing gases at flammable concentrations should only be prepared under controlled conditions, normally at low pressure. Flammability limits can change markedly with pressure and temperature. This International Standard does not, however, give any information about the ways in which such mixtures can be prepared. In such cases, a careful analysis using other data is necessary.

4.6.2.1 The calculation given for oxidizing mixtures (see 5.3) will show if the mixture is more oxidizing than air.

4.6.2.2 If the mixture is less oxidizing than air, calculate, as above, whether the mixture which is obtained by eliminating the oxidizing agents is flammable in air. If this is the case, the initial mixture is taken to be flammable in air.

Otherwise, carry out a test measurement to check if the mixture is flammable in air.

However, a mixture can be considered as non-flammable without carrying out a test measurement if one of the following conditions is fulfilled:

a) Condition 1

The mixture obtained by eliminating the oxidizing agents is not flammable in air, and the initial mixture is composed of less than 0,5 % of oxygen equivalent (calculated in accordance with 5.3).

b) Condition 2

The sum of the flammable-gas contents in the initial mixture is less than 90 % of the lower flammability limit in air of the flammable-gas mixture. This occurs when the following condition is fulfilled:

$$\sum \frac{A_i}{0{,}9 \times L_i} \times 100 < 1$$

where

A_i is the molar fraction of the ith flammable gas;

L_i is the lower flammability limit in air of the ith flammable gas (see annex A).

EXAMPLE 3

Consider a mixture comprising 2 % H_2 + 1 % CH_4 + 13 % O_2 + 84 % N_2.

1) The mixture obtained by eliminating the oxidizing agents is

$$2{,}3\ \%\ H_2 + 1{,}15\ \%\ CH_4 + 96{,}55\ \%\ N_2.$$

Since the sum

$$\frac{2{,}3}{5{,}7} + \frac{1{,}15}{14{,}3} = 0{,}48$$

is less than 1, the mixture obtained by eliminating the oxidizing agents is not flammable in air.

2) The mixture contains more than 0,5 % of oxygen equivalent. Condition 1 is thus not fulfilled.

3) The calculation to check condition 2

$$\frac{2}{0{,}9 \times 4} + \frac{1}{0{,}9 \times 5} = 0{,}78$$

shows that the mixture is not flammable in air.