Transportable gas cylinders — Gases and gas mixtures

Part 2. Determination of flammability and oxidizing ability of gases and gas mixtures

The European Standard EN 720-2 : 1996 has the status of a British Standard

ICS 71.100.20; 75.160.30

Committees responsible for this British Standard

The preparation of this British Standard was entrusted to Technical Committee PVE/3, Gas containers, upon which the following bodies were represented:

Aluminium Extruders' Association
Aluminium Federation
British Compressed Gases Association
British Fire Consortium
British Gas plc
British Iron and Steel Producers' Association
British Soft Drinks Association Ltd.
Engineering Equipment and Materials Users' Association
Fire Extinguishing Trades Association
Health and Safety Executive
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LP Gas Association
Marine Safety Agency
Ministry of Defence
National Engineering Laboratory
National Physical Laboratory
Safety Assessment Federation Ltd.
Safety Equipment Association
Tube Investments Chesterfield Tube Co. Ltd.
Tubes Investments Limited

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British Association of Breathing Apparatus Service Engineers
Department of Health

This British Standard, having been prepared under the direction of the Engineering Sector Board, was published under the authority of the Standards Board and comes into effect on
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Contents

National foreword

This British Standard has been prepared by Technical Committee PVE/3 and is the English language version of EN 720-2 : 1996 *Transportable gas cylinders — Gases and gas mixtures Part 2. Determination of flammability and oxidizing ability of gases and gas mixtures* published by the European Committee for Standardization (CEN).

EN 720-2 was produced as a result of international discussions in which the United Kingdom took an active part.

There has previously been no British Standard directly equivalent to this standard.

Cross-reference

International Standard	Corresponding British Standard
	BS 2782 *Methods of testing plastics*
	Part 1 *Thermal properties*
ISO 4589	Method 141 : 1986 *Determination of flammability of oxygen index*

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, the EN title page, pages 2 to 14, an inside back cover and a back cover.

EUROPEAN STANDARD

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Descriptors: Gas, gas mixtures, flammable gases, classifications, flammability testing, oxidation tests, computation, flammability, toxicity, tables (data)

English version

Transportable gas cylinders — Gases and gas mixtures Part 2: Determination of flammability and oxidizing ability of gases and gas mixtures

Bouteilles à gaz transportables — Gaz et mélanges de gaz — Partie 2: Détermination du potentiel d'inflammabilité et d'oxydation des gaz et mélanges de gaz

Ortsbewegliche Gasflaschen — Gase und Gasgemische — Teil 2: Bestimmung der Brennbarkeit und des Oxidationsvermögens von Gasen und Gasgemischen

This European Standard was approved by CEN on 1996-02-10. CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Central Secretariat has the same status as the official versions.

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CEN

European Committee for Standardization

Comité Européen de Normalisation

Europäisches Komitee für Normung

Central Secretariat: rue de Stassart 36, B-1050 Brussels

Foreword

This European Standard has been prepared by Technical Committee CEN/TC 23, Transportable gas cylinders, the secretariat of which is held by BSI.

This European Standard is a two Part standard, belonging to a series of standards relating to gases and gas mixtures:

Part 1. *Properties of single component gases*;

Part 2. *Determination of flammability and oxidizing ability of gases and gas mixtures*.

ISO Standard ISO 10156 was used as a base document.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by January 1997, and conflicting national standards shall be withdrawn at the latest by January 1997.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

Contents

1 Scope

This standard identifies test and calculation methods for the determination of flammability and oxidizing ability of gases and gas mixtures. The first test method determines whether or not a gas is flammable in air. The second test method determines if a gas or gas mixture has a greater or lesser oxidizing ability than that of air.

The calculation method uses the characteristics of the pure substances, of which the mixture is composed, to determine the characteristics of the mixture.

The results of the methods of determination, described in this standard, are intended to assist in the selection of safe gas cylinder valve outlet connections.

2 Normative references

This European Standard incorporates by dated or undated references, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies.

ISO 4589 *Plastics — Determination of flammability by oxygen index*

3 Definitions and symbols

3.1 Definitions

For the purposes of this 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 a temperature of 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.
A_i'	Equivalent content of a flammable gas.
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.
K_i	Coefficient of equivalency of an inert gas relative to nitrogen.
L_i	Lower flammability limit, in air, of a flammable gas.
n	Number of flammable gases in a gas mixture.
p	Number of inert gases in a gas mixture.
T_{ci}	Maximum flammable gas content for which a mixture of the flammable gas in nitrogen is not flammable in air.
x_i	Concentration of a highly oxidizing gas.
y_i	Minimum concentration of an oxidizing combustion gas, in a mixture with nitrogen, which will support combustion of a test piece, having a limiting oxygen index equal to 21 %.
Ar	Argon.
CF_4	Carbon tetrafluoride.
C_3F_8	Octofluoropropane.
CH_4	Methane.
CO_2	Carbon dioxide.
He	Helium.
H_2	Hydrogen.
Kr	Krypton.
Ne	Neon.
N_2	Nitrogen.
N_2O	Nitrous oxide.
O_2	Oxygen.
SF_6	Sulfur hexafluoride.
SO_2	Sulfur dioxide.
Xe	Xenon.

4 Flammability of gases and gas mixtures in air

4.1 General

It is necessary to identify gases and gas mixtures which are flammable. Such gases and gas mixtures have flammable limits in air. The following subclauses outline test and calculation methods for determining whether a gas or gas mixture is considered to be flammable. In cases where the test result is different to that achieved by calculation, the test result shall take precedence.

4.2 Test method

The gas is mixed, in the desired proportions, with air. An ignition energy is applied, from an electric arc across two electrodes (e.g. a spark plug).

4.3 Equipment

The equipment includes (see figure l):

– a mixing apparatus;

– a chamber in which the reaction takes place;

– an ignition system;

– systems of analysis to test the gas compositions.

4.3.1 ***Reaction chamber*** (see figure 1)

The reaction chamber shall be made of suitable material, of adequate thickness (e.g. borosilicate glass, 5 mm thick), having an inside diameter of at least 50 mm and a length of at least 5 times the diameter.

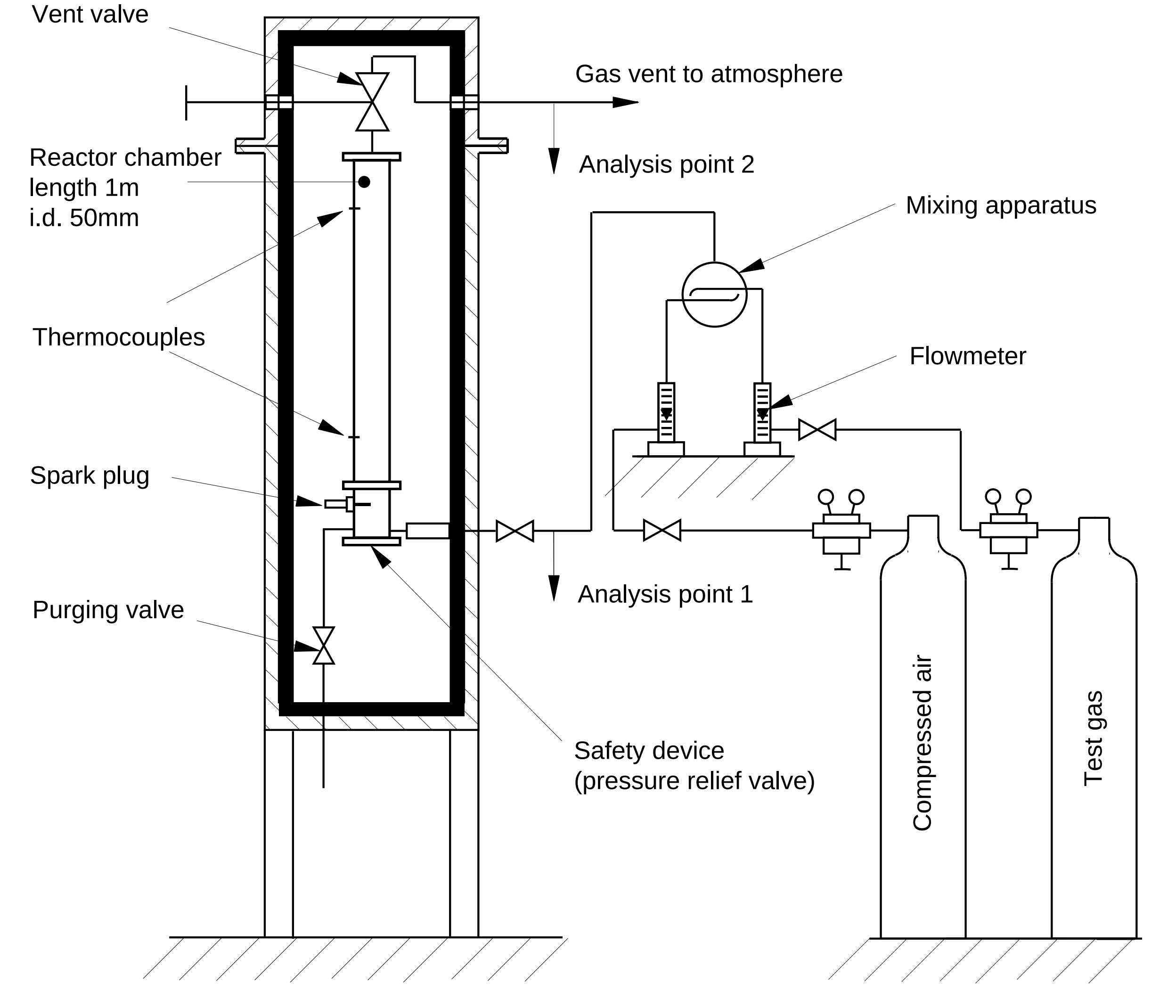

Figure 1. Example of equipment for the determination of flammability limits of gases, at atmospheric pressure and ambient temperature

The reaction chamber shall incorporate the following:

– an ignition spark plug located approximately 50 mm from the base of the chamber;

– an inlet for the gas mixture being tested;

– a purging valve, at the bottom;

– two thermocouples, one close to the spark plug and the other close to the top of the chamber. The purpose of these thermocouples is to detect flame propagation;

– a safety device (preferably located close to the spark plug), to minimize the risk of destruction of the chamber, in the event of an explosion;

– a vent valve, at the top, to atmosphere.

The reaction chamber is positioned inside a ventilated protective enclosure, one side of which has a window made of high strength transparent material. In a dark room, this window will enable detection of an ignition by an experienced observer. This visual detection is not possible with the almost colourless flames of hydrogen mixtures, for which thermocouples should be used.

4.3.2 ***Flow measurement***

Volume flowmeters, mass flowmeters and other appropriate devices, such as proportioning pumps, may be used.

4.4 Preparation

4.4.1 ***Test gas***

The gas or gas mixture to be tested shall be prepared to represent the most flammable composition that can occur in the normal course of manufacture. The test gas shall reflect the manufacturing tolerances and shall contain the upper limit of flammable gases encountered in manufacture. The moisture content shall be equal to or lower than 10 p.p.m. *(V/V)*. The test gas shall be thoroughly mixed and carefully analysed to determine its exact composition.

4.4.2 ***Compressed air***

The compressed air shall be analysed and be shown to have a moisture level equal to, or lower than 10×10^{-6} p.p.m. *(V/V)*.

4.4.3 ***Test gas/air mixture***

The compressed air and the gas to be tested shall be mixed, at controlled flowrates, using a dynamic mixer. The gas mixture shall be analysed, using either a chromatograph or a simple oxygen analyser.

4.4.4 ***Flammable/oxidizing/inert gas mixtures***

Mixtures containing flammable and oxidizing gases at flammable concentrations shall only be manufactured under controlled conditions, normally at low pressure. Flammability limits can vary significantly with change of pressure and temperature. This standard does not cover the preparation of such mixtures; in such cases careful analysis, using other data, is necessary.

4.5 Procedure

The reaction chamber and its accessories shall be cleaned prior to any test to avoid the effect of any impurity, particularly moisture, resulting from any previous combustion, or exposure to the atmosphere.

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

The desired mixture shall be blended, using the flow meters and mixing equipment. The mixture shall be carefully analysed, at analysis point 2 (see figure 1). Close the gas inlets simultaneously. Just prior to ignition, open the vent valve to bring the mixture to atmospheric pressure.

There are several possible outcomes.

a) *No combustion.* The mixture of the test gas at this concentration is not considered to be flammable in air.

The test shall be repeated 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.

The test shall be repeated at least five times. If, in at least one case, the flame rises up the tube, this indicates that the flammability limit has been reached i.e. the test gas is considered to be flammable.

c) *The flame rises slowly up the tube some* 10 cm/s *to* 50 cm/s. This indicates that the flammability limit has been reached i.e. the test gas is considered to be flammable.

d) *The flame rises up the tube very rapidly.* This indicates that the test gas is considered to be flammable.

NOTE. It is beyond the scope of this standard, but if a precise value is required for the lower flammability limit of the test gas, then repeated tests may be carried out (varying the flammable gas content) until the threshold point is reached, between ignition and no ignition, of the flammable gas.

4.6 Key safety points

Tests shall be carried out by trained and competent personnel working according to authorized procedures. The reaction chamber and flow meter shall be adequately screened to protect personnel in the event of explosion. Personnel shall wear safety glasses. During the ignition sequence, the reaction chamber shall be opened to the atmosphere and isolated from the gas supply. Care shall be taken during the analysis of the test gas or gas mixture.

4.7 Results for pure gases

Flammable gases are listed in annex A, together with some lower flammability limits. These values have been obtained using similar test equipment to that described in **4.3**.

4.8 Calculation method

The use of this method is limited to gas mixtures produced in small quantities, in cylinders, to indicate if flammable in air.

4.8.1 *Mixtures containing n flammable gases and p inert gases*

The mixture is 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	Molar fraction of a flammable gas in a mixture of gases.
B_i	Molar fraction of an inert gas in a mixture of gases.
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.

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 coefficients of equivalency K_i values given in table 1:

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

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

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

where

$$\frac{A_i}{\Sigma A_i + \Sigma K_iB_i} = A_i'$$

is the equivalent flammable gas content.

Table 1. Coefficients of equivalency (K_i), for selected gases relative to nitrogen

Chemical formula	Gas name	Coefficientof equivalency K_i
N_2	Nitrogen	1
CO_2	Carbon dioxide	1,5
He	Helium	0,5
Ar	Argon	0,5
Ne	Neon	0,5
Kr	Krypton	0,5
Xe	Xenon	0,5
SO_2	Sulfur dioxide	1,5
SF_6	Sulfur hexafluoride	1,5
CF_4	Tetrafluoromethane (carbon tetrafluoride)	1,5
C_3F_8	Octofluoropropane	1,5

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

NOTE 2. These data are deliberately conservative to ensure that the calculation results are correspondingly conservative and safe, especially since few published data are available.

NOTE 3. For other inert gases, which contain 3 or more atoms, as shown in their chemical formulae, the coefficient of equivalency, K_i = 1,5 shall be used.

Table 2 gives values for the maximum content T_{ci} (expressed as volume per cent) of flammable component which, in a mixture with nitrogen, gives a composition which is not considered to be flammable in air. Expressed mathematically this condition for the mixture not being considered flammable in air is:

$$\Sigma \frac{A_i'}{T_{ci}} \times 100 \leq 1$$

Example 1

Consider a mixture comprising 7 % H_2 and 93 % CO_2, by volume.

Using the appropriate K_i value from table 1 and expressing the composition in molar fraction, this mixture is equivalent to:

$$0{,}07\ H_2 + (1{,}5 \times 0{,}93)\ N_2$$

i.e.

$$0{,}07\ H_2 + 1{,}395\ N_2$$

Then calculate A_i'

$$A_i' = \frac{0{,}07}{0{,}07 + 1{,}395} = 0{,}0478$$

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

Since: $\frac{0{,}0478}{5{,}7} \times 100 = 0{,}8386$

is less than 1, the mixture is not considered to be flammable in air.

Example 2

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

Using the appropriate K_i value from table 1 and expressing the composition in molar fractions, this mixture is equivalent to:

0,02 H_2+ 0,08 CH_4 + {(0,5 × 0,25) + (0,5 × 0,65)} N_2

i.e.

0,02 H_2 + 0,08 CH_4 + 0,45 N_2

Calculate for A'_1 for H_2

$$A_i' = \frac{0{,}02}{0{,}02 + 0{,}08 + 0{,}45} = 0{,}0364$$

Calculate for A_i' for CH_4

$$A_i' = \frac{0{,}08}{0{,}02 + 0{,}08 + 0{,}45} = 0{,}1455$$

Since the sum of $\frac{0{,}0364 \times 100}{5{,}7} + \frac{0{,}1455 \times 100}{14{,}3}$

$= 0{,}6386 + 1{,}0168 = 1{,}6554$

is greater than 1 the mixture is considered to be flammable in air.

4.8.2 ***Mixtures containing one or more flammable gases and one or more oxidizing gases plus one or more inert gases*** (see **4.4.4**)

4.8.2.1 The calculation given for oxidizing mixtures (see **5.3**) will show if the mixture has a greater oxidizing ability than that of air.

4.8.2.2 If the mixture has a lesser oxidizing ability than that of air, calculate as in **4.8.1** whether the mixture, which is obtained by eliminating the oxidizing agents, is flammable in air. If this is the case then the initial mixture shall be considered 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.

– 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**).

– 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 agents mixture. This occurs when the following condition is fulfilled.

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

where:

A_i Molar fraction of a flammable gas in a mixture of gases.

L_i Lower flammability limit, in air, of a flammable gas (see annex A).

Example 3

Consider a mixture comprising: 2 % H_2 + 1 % CH_4 + 13 % O_2 + 84 % N_2, by volume.

The mixture obtained, by eliminating the oxidizing agents and expressing the composition in molar fraction, is equivalent to:

0,02 H_2 + 0,01 CH_4 + 0,84 N_2

Adjusting the sum of the molar fraction to 1, the expression for the composition becomes:

0,023 H_2 + 0,0115 CH_4 + 0,9655 N_2 = 1

Since the sum of:

$$\frac{0{,}023 \times 100}{5{,}7} + \frac{0{,}0115 \times 100}{14{,}3} = 0{,}4035 + 0{,}0804 = 0{,}4839$$

is less than 1, the mixture obtained, by eliminating the oxidizing agent, is not considered to be flammable in air.

The mixture contains more than 0,5 % of oxygen equivalent.

Condition 1) is not fulfilled.

Calculation to check condition 2):

$$\frac{0{,}02 \times 100}{0{,}9 \times 4} + \frac{0{,}01 \times 100}{0{,}9 \times 5} = 0{,}7778$$

Since this result is less than 1, the mixture is not considered to be flammable in air.

Example 4

Consider a mixture comprising: 1 % H_2 + 4 % CH_4 + 11 % O_2 + 84 % He, by volume.

The mixture obtained by eliminating the oxidizing agents and expressing the composition in molar fraction, is equivalent to:

0,01 H_2 + 0,04 CH_4 + (0,84 × 0,5) N_2

i.e.

0,01 H_2 + 0,04 CH_4 + 0,42 N_2

adjusting the sum of the molar fraction to 1, the expression for the composition becomes:

0,0213 H_2 + 0,0851 CH_4 + 0,8936 N_2 = 1

Since the sum:

$$\frac{0{,}0213 \times 100}{5{,}7} + \frac{0{,}0851 \times 100}{14{,}3} = 0{,}3737 + 0{,}5951$$

$= 0{,}9688$

is less than 1, the mixture, is not considered to be flammable in air.

The mixture contains more than 0,5 % of oxygen equivalent.

Condition 1) is not fulfilled.

Calculation to check condition 2):

$$\frac{0{,}01 \times 100}{0{,}9 \times 4} + \frac{0{,}04 \times 100}{0{,}9 \times 5} = 1{,}1667$$

since the result is greater than 1, the mixture may be considered to be flammable in air.

In this case it is necessary to carry out a test measurement to demonstrate the validity of the result.

Table 2. Examples of flammable components, showing maximum content (T_{ci}) which, in a mixture with nitrogen, give a composition which is not flammable in air

Gas name	Maximum content T_{ci}(% *V/V*)[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
Methylformate	7
Methylacetate	4,3
Ethylformate	3,9
Methyl ethyl ketone	2
Hydrogen sulfide	5,2
Carbon disulfide	1,5
Fluoromethane	3,7

Table 2. Examples of flammable components, showing maximum content (T_{ci}) which, in a mixture with nitrogen, give a composition which is not flammable in air *(continued)*

Gas name	Maximum content T_{ci}(% *V/V*)[1)]
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
Ethyl acetylene	1,8
Methyl acetylene	1,4

1) When impossible to find the T_{ci} data, a conservative and therefore more reliable value of 1 is inserted.

5 Oxidizing ability of gases and gas mixtures

5.1 General

Gases and gas mixtures, with oxidizing ability, will support combustion more vigorously or less vigorously than air. The following methods are proposed to determine if a gas or gas mixture is considered to have oxidizing ability, greater than that of air ('highly oxidizing').

5.2 Test method

5.2.1 *General*

The recommended test method is based on that described in ISO 4589.

The purpose of ISO 4589 is:

– to determine the oxygen index. This index, given as a percentage, is the determination of the minimum percentage of oxygen, in an oxygen–nitrogen mixture, that promotes combustion, with the formation of flames, of a specified test material.

5.2.2 *Test pieces*

Using the equipment described in ISO 4589, select test pieces, of plastic or any other suitable material, having an oxygen index equal to 21 %.

5.2.3 *Procedure*

Using the same equipment, perform a test (according to the procedures and criteria of ISO 4589) to see if the test pieces, when suspended in the gas or gas mixture whose oxidizing ability is to be determined, are combustible.

If combustion is supported, the gas or gas mixture is to be considered to have an oxidizing ability greater than that of air ('highly oxidizing').

Atmospheric air has an oxygen concentration by volume of 20,95 % and shall thus not be considered as 'highly oxidizing'.

5.2.4 *Applicability*

When applying this test method to pure gases, oxygen and nitrous oxide have been found to have a greater oxidizing ability than that of air.

5.3 Calculation method

This method is only applicable to special gas mixtures in small quantities, in cylinders. The effect of balance gases is not considered.

The 'highly oxidizing' gases oxygen, and nitrous oxide are used, their respective concentrations x_i, in a mixture, being expressed as a percentage by volume.

If the following condition is satisfied:

$$\Sigma\, x_i C_i \geq 21$$

where C_i is the coefficient of oxygen equivalency (specific to each gas), then the mixture is considered to be more oxidizing than air.

By definition, C_i = 1 for oxygen. In the case of nitrous oxide, C_i = 0,6.

By this method, atmospheric air would have:

$$\Sigma\, x_i C_i = 20{,}95$$

and is therefore not considered as 'highly oxidizing'

Where required, C_i coefficients for other oxidizing gases may be calculated using the formula:

$$C_i = \frac{21}{\Sigma y_i}$$

where y_i is the minimum concentration (expressed as a percentage by volume) of the oxidizing gas in question in a mixture with nitrogen, which will support the combustion of a test piece having an oxygen index equal to 21 % (in accordance with ISO 4589).

Example 1

Consider a mixture comprising:

$9\ \%\ O_2 + 16\ \%\ N_2O + 75\ \%\ N_2$.

This gives:

$$\Sigma\, x_i C_i = (9 \times 1) + (16 \times 0{,}6) = 18{,}6$$

which is < 21. This mixture is therefore considered to be less oxidizing than air.

Example 2

Consider a mixture comprising:

$10\ \%\ O_2 + 50\ \%\ N_2O + 20\ \%\ N_2 + 20\ \%\ Ar$.

This gives:

$\Sigma\, x_i C_i = (10 \times 1) + (50 \times 0{,}6) = 40$ which is > 21.

This mixture is therefore considered more oxidizing than air (highly oxidizing).

Annex A (normative)
Lower flammability limit (L_i), in air, of pure gases classified by group

Table A.1 Group 1 — Flammable and non-toxic gases

Gas	Synonym	L_i %
Allene	Propadiene	2,16
Bromotrifluoroethylene	R113B1	*)
Butane		1,8
1 -Butene	Butylene	1,6
2 -Butene	Butylene	1,7
Chlorofluoromethane	R31	*)
1-Chloro-1,1-difluoroethane	R142b	4,4
Deuterium		4,9
1,1-Difluoroethane	Ethylidine fluoride R152a	3,7
1,1-Difluoroethylene	Vinylidene fluoride R1132a	5,5
Dimethyl ether	Methyl ether	3,4
2,2-Dimethylpropane	Neopentane; tetramethylmethane	1,4
Ethane	R170	3
Ethylacetylene	1-Butyne	*)
Ethyl chloride (flammable liquid)	Chloroethane R160	3,8
Ethylene	Ethene	2,7
Ethyl ether	R1150	1,9
Hydrogen		4
Isobutane	Trimethylmethane R601	1,8
Isobutylene	Isobutene; 2-methylpropene	1,8
Methane	R50	5
Methyl acetylene	Allylene; propyne	1,7
Methyl-3-butene	Isoamylene; isopropylethylene	1,3
Methyl ethyl ether	Ethyl methyl ether	2
Methyl fluoride	Fluoromethane R41	*)
Natural gas		≈ 5 depending on composition
Propane	R290	2,1
Propylene	Propene R1270	2,4
1,1,1-Trifluoroethane	R143a	4,5

*) Unknown.

Table A.2 Group 2 — Flammable, toxic and corrosive gases (basic)		
Gas	**Synonym**	L_i %
Ammonia	R717	15
Dimethylamine		2,8
Monoethylamine	Ethylamine R631	3,5
Monomethylamine	Methylamine R630	4,2
Trimethylamine		2

Table A.3 Group 3 — Flammable, toxic and corrosive gases (acidic), and flammable non-corrosive gases		
Gas	**Synonym**	L_i %
Arsine		4,5
Carbon monoxide		12,5
Carbonyl sulfide	Carbonoxylsulfide	1,3
Chloromethane	Methyl chloride R40	10,7
Coal gas		*)
Cyanogen		6,6
Cyclopropane	Trimethylene	2,4
Deuterium selenide		*)
Deuterium sulfide		*)
Dichlorosilane		*)
Dimethylsilane		*)
Fluoroethane	Ethyl fluoride	*)
Germane		*)
Heptafluorobutyronotrile		*)
Hexafluorocyclobutene		*)
Hydrogen selenide		*)
Hydrogen sulfide		4
Methyl mercaptan	Methanethiol	3,8
Methylsilane		*)
Nickel carbonyl	Nickel tetracarbonyl	0,9
Pentafluoropropionitrile		*)
Tetraethyl lead		*)
Tretramethyl lead		1,8
Trifluoroacetonitrile		*)
Trifluoroethylene		10,5
Trimethylsilane		*)
*) Unknown.		

Table A.4 Group 4 — Spontaneously flammable gases		
Gas	**Synonym**	L_i %
Diethylzinc		*)
Penaborane		*)
Phosphine		1,8
Silane	Silicon tetrahydride	*)
Triethyl aluminium		*)
Triethyl borane		*)
Trimethylstibine		*)
*) Unknown.		

Table A.5 Group 5 — Flammable gases, subject to decomposition or polymerization		
Gas	**Synonym**	L_i %
1,3-Butadiene (inhibited)		1,3
Chlorotrifluoroethylene	R1113	4,6
Diborane		0,8
Ethylene oxide	Oxirane	3,6
Hydrogen cyanide	Hydrocyanic acid (anhydrous)	5,6
Propylene oxide	Methyl oxirane	2,8
Stibine	Antimony hydride	*)
Vinyl bromide (inhibited)	Bromoethylene	5,5
Vinyl chloride (inhibited)	Chloroethylene R1140	3,6
Vinyl fluoride (inhibited)	Fluoroethylene R1141	2,9
*) Unknown.		

Table A.6 Group 6 — Flammable, subject to decomposition, non-toxic, dissolved, non-corrosive gases		
Gas	**Synonym**	L_i %
Acetylene	Ethyne	2,4

Annex B (informative)
Example of alternative equipment for the determination of flammability limits of gases at atmospheric pressure and ambient temperature

B.1 Ignition system

A spark generator (e.g. 15 kV) shall be used which can supply sparks, across a distance (e.g. 5 mm) between electrodes, with an energy of 10 joules per spark.

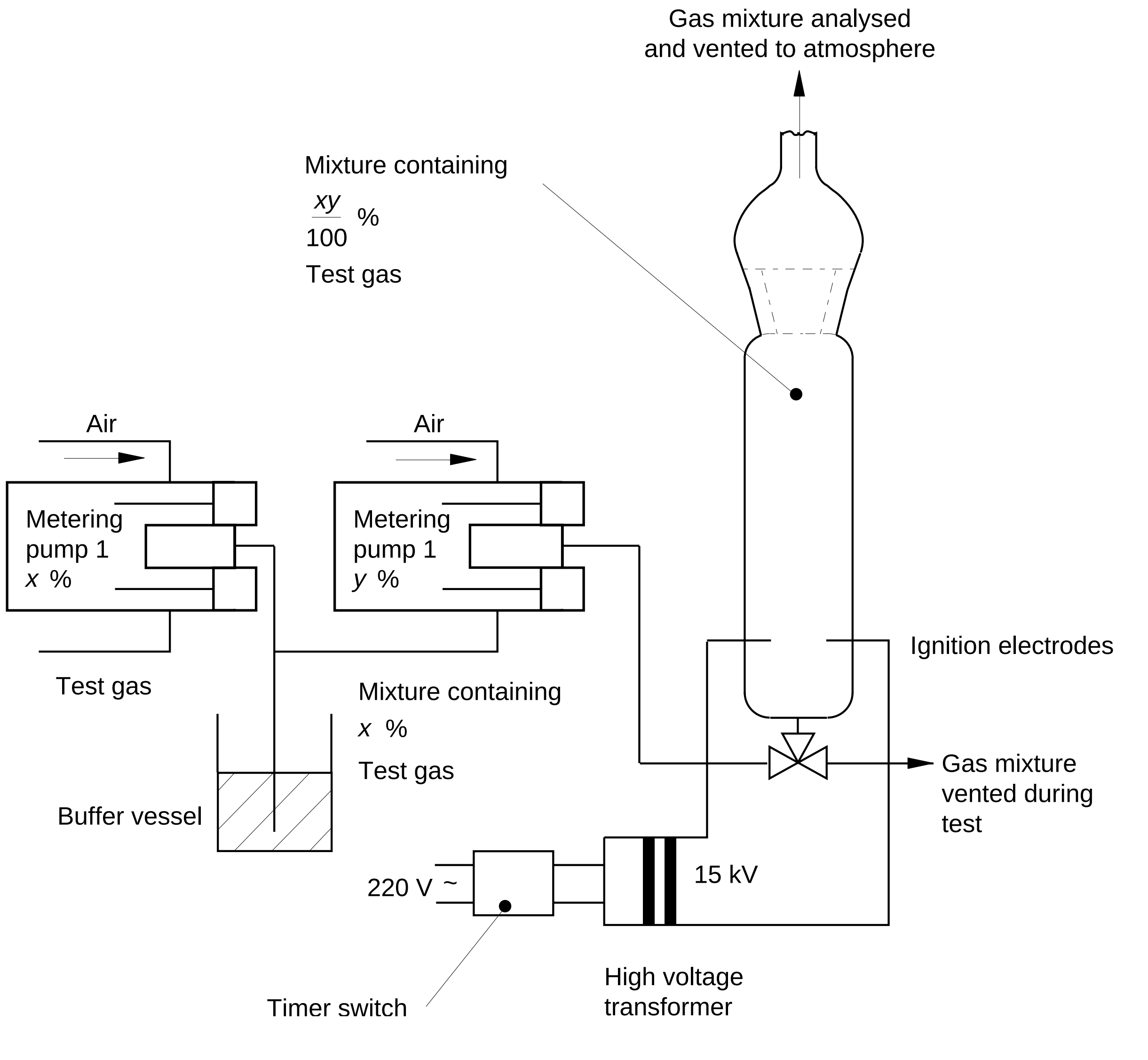

Figure B.1 Example of alternative equipment for the determination of flammability limits of gases at atmospheric pressure and ambient temperature

List of references

See national foreword.

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