INTERNATIONAL STANDARD

ISO 3821

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Gas welding equipment — Rubber hoses for welding, cutting and allied processes

Matériel de soudage aux gaz — Tuyaux souples en caoutchouc pour le soudage, le coupage et les techniques connexes

Reference number
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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. 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.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 3821 was prepared by Technical Committee ISO/TC 44, *Welding and allied processes*, Subcommittee SC 8, *Equipment for gas welding, cutting and allied processes*.

This fourth edition cancels and replaces the third edition (ISO 3821:1998), which has been technically and editorially revised.

Requests for official interpretations of any aspect of this International Standard should be directed to the Secretariat of ISO/TC 44/SC 8 via your national standards body. A complete listing of these bodies can be found at www.iso.org.

Gas welding equipment — Rubber hoses for welding, cutting and allied processes

1 Scope

This International Standard specifies requirements for rubber hoses (including twin hoses) for welding, cutting and allied processes.

This International Standard specifies requirements for rubber hoses for normal duty of 2 MPa (20 bar) and light duty [limited to hoses for maximum working pressure of 1 MPa (10 bar) and with bore up to and including 6,3 mm].

This International Standard applies to hoses operated at temperatures −20 °C to +60 °C and used in:

— gas welding and cutting;

— arc welding under the protection of an inert or active gas;

— processes allied to welding and cutting, in particular, heating, brazing, and metallization.

This International Standard applies neither to thermoplastics hoses nor to hoses used for high pressure [>0,15 MPa (>1,5 bar)] acetylene.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 37, *Rubber, vulcanized or thermoplastic — Determination of tensile stress-strain properties*

ISO 188, *Rubber, vulcanized or thermoplastic — Accelerated ageing and heat resistance tests*

ISO 1307:2006, *Rubber and plastics hoses — Hose sizes, minimum and maximum inside diameters, and tolerances on cut-to-length hoses*

ISO 1402, *Rubber and plastics hoses and hose assemblies — Hydrostatic testing*

ISO 1746, *Rubber or plastics hoses and tubing — Bending tests*

ISO 1817, *Rubber, vulcanized — Determination of the effect of liquids*

ISO 4080, *Rubber and plastics hoses and hose assemblies — Determination of permeability to gas*

ISO 4671, *Rubber and plastics hoses and hose assemblies — Methods of measurement of the dimensions of hoses and the lengths of hose assemblies*

ISO 4672:1997, *Rubber and plastics hoses — Sub-ambient temperature flexibility tests*

ISO 7326:2006, *Rubber and plastics hoses — Assessment of ozone resistance under static conditions*

ISO 8033:2006, *Rubber and plastics hoses — Determination of adhesion between components*

ISO 8330, *Rubber and plastics hoses and hose assemblies — Vocabulary*

ISO 11114-3, *Transportable gas cylinders — Compatibility of cylinder and valve materials with gas contents — Part 3: Autogenous ignition test in oxygen atmosphere*

ISO 23529, *Rubber — General procedures for preparing and conditioning test pieces for physical test methods*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 8330 and the following apply.

3.1
twin hose
two normal rubber hoses joined together longitudinally

3.2
universal fuel gas hose
hoses which can be used for all fuel gases except fluxed fuel gas

NOTE Fuel gases are listed in Table 4.

3.3
flux fuel gas hose
hose suitable for fuel gas containing a flux

4 Abbreviated terms

For the purposes of this document, the following abbreviations apply.

LPG liquefied petroleum gases

MPS methylacetylene-propadiene mixtures

5 Application

Hoses shall only be used for the gas service for which they are identified (see 10.2).

6 Hose designation

The hoses covered by this International Standard are designated using the following information:

a) nominal bore, see Table 1;

b) light or normal duty (pressure rating), see Table 3;

c) colour and marking (gas service), see Table 4.

EXAMPLE 1 6,3 mm, light duty.

EXAMPLE 2 10 mm, normal duty.

EXAMPLE 3 6,3 mm, light duty, FLUX.

7 Materials

7.1 Construction

7.1.1 General

The hose shall consist of:

a) a rubber lining of minimum thickness 1,5 mm;

b) reinforcement applied by any suitable technique;

c) a rubber cover of a minimum thickness of 1,0 mm.

7.1.2 Flux fuel gas hose

The flux fuel gas hose shall consist of:

a) a rubber lining with an additional inner plastic layer, which shall be of maximum thickness 0,5 mm, to give a minimum total thickness of 1,5 mm;

b) reinforcement applied by any suitable technique;

c) a rubber cover of minimum thickness 1,0 mm.

7.1.3 Twin hose

Each hose used for twin hose construction shall be as specified in 7.1.1 or 7.1.2. The two hoses shall be joined longitudinally during the extrusion and/or vulcanization process. They shall be capable of being separated free of damage to enable end fittings to be fitted. See 9.3.7.

7.2 Manufacture

The lining and cover shall be of uniform thickness and free from holes, porosity and other defects.

8 Dimensions and tolerances

8.1 Internal diameter

The internal diameter of the hoses shall be in accordance with the dimensions and tolerances shown in Table 1.

Table 1 — Nominal bore, internal diameter, tolerances and concentricity

<table>
<tr><th>Nominal bore</th><th>Internal diameter
mm</th><th>Tolerance
mm</th><th>Concentricity max.
mm</th></tr>
<tr><td>4</td><td>4</td><td rowspan="5">±0,40</td><td rowspan="10">1</td></tr>
<tr><td>4,8</td><td>4,8</td></tr>
<tr><td>5</td><td>5</td></tr>
<tr><td>6,3</td><td>6,3</td></tr>
<tr><td>7,1</td><td>7,1</td></tr>
<tr><td>8</td><td>8</td><td rowspan="3">±0,50</td></tr>
<tr><td>9,5</td><td>9,5</td></tr>
<tr><td>10</td><td>10</td></tr>
<tr><td>12,5</td><td>12,5</td><td rowspan="4">±0,60</td></tr>
<tr><td>16</td><td>16</td></tr>
<tr><td>20</td><td>20</td><td rowspan="3">1,25</td></tr>
<tr><td>25</td><td>25</td></tr>
<tr><td>32</td><td>32</td><td>±1,0</td></tr>
<tr><td>40</td><td>40</td><td rowspan="2">±1,25</td><td rowspan="2">1,50</td></tr>
<tr><td>50</td><td>50</td></tr>
<tr><td colspan="4">NOTE 1 The tolerances and internal diameters (excluding nominal bore of 20 mm) do not comply with ISO 1307:2006, Table 1.
NOTE 2 For intermediate dimensions, numbers should be chosen from the R20 series of preferred numbers (see ISO 3) with tolerances as for the next larger internal diameter listed.</td></tr>
</table>

8.2 Concentricity (total indicator reading)

The concentricity of the hose, measured in accordance with ISO 4671, shall be in accordance with the values given in Table 1.

8.3 Cut lengths and tolerances

The tolerances for cut lengths shall be in accordance with ISO 1307.

9 Requirements and type tests

9.1 General

A summary of requirements and type tests with the corresponding number of samples is given in Annex D.

9.2 Basic requirements

9.2.1 Tensile strength and elongation at break

Measurements shall be made on test specimens cut from the hoses. The materials used in the lining and cover, when tested in accordance with ISO 37, shall have a tensile strength and elongation at break not less than the values given in Table 2.

Table 2 — Tensile strength and elongation at break

Rating	Tensile strength MPa	Elongation at break %
Rubber lining	5	200
Cover	7	250
Inner plastic layer	5	120

9.2.2 Accelerating ageing

Measurements shall be made on test specimens cut from the hoses. After ageing for 7 days at a temperature of 70 °C as specified in ISO 188 (air oven), the tensile strength and elongation at break respectively of the lining and cover shall not decrease from the original values obtained by more than 25 % for the tensile strength and 50 % for elongation at break.

9.2.3 Adhesion

When tested in accordance with ISO 8033:2006 using the type 2 or type 4 test piece, the minimum adhesion between adjacent components shall be 1,5 kN/m. For flux fuel gas hoses, see 9.3.4. For flux fuel gas hoses, the inner plastic lining should be removed prior to the test.

9.2.4 Hydrostatic requirements

The hose, when tested in accordance with ISO 1402 at ambient temperature, shall meet the requirements of Table 3.

Table 3 — Hydrostatic requirements

Rating	Light duty (Nominal bore ⩽6,3)	Normal duty (all sizes)
Maximum working pressure	1 MPa (10 bar)	2 MPa (20 bar)
Proof pressure	2 MPa (20 bar)	4 MPa (40 bar)
Minimum burst pressure	3 MPa (30 bar)	6 MPa (60 bar)
Change in length at maximum operating pressure	±5 %	
Change in diameter at maximum operating pressure	±10 %	

9.2.5 Flexibility, general

When tested in accordance with ISO 1746 at standard laboratory temperature as defined in ISO 23529 using a diameter of curvature, D_c, of $10d_i$, where d_i is the internal diameter (with a minimum of 80 mm), the coefficient of deformation, K, shall not be less than 0,8. There shall be no kink in the curved portion of the hose.

9.2.6 Low-temperature flexibility

When tested in accordance with ISO 4672:1997, method B, at (–25 ± 3) °C, using a D_c of $10d_i$ (with a minimum of 80 mm), the hose shall show no signs of leakage when subjected to the proof pressure (carried out at ambient temperature) stated in Table 3.

9.2.7 Resistance to incandescent particles and hot surfaces

The cover of the hose shall have sufficient resistance to contact with incandescent particles and hot surfaces. To meet this requirement, the test piece shall resist for 60 s the test conditions given in Annex C without leaking.

If the first test fails, the two subsequent tests shall be satisfactory.

9.2.8 Ozone resistance

Hoses up to 25 mm internal diameter shall be tested in accordance with ISO 7326:2006, method 1, using a D_c as specified in 9.2.5. Hoses above 25 mm internal diameter shall be tested in accordance with ISO 7326:2006 method 3. For both methods the cover shall show no evidence of cracking when viewed under two times magnification.

9.3 Special requirements

9.3.1 Non-ignition requirement for oxygen hoses

The non-ignition test shall be carried out either according to ISO 11114-3 or Annex A.

When tested according to ISO 11114-3 the initial conditions shall be set at 2 MPa (20 bar) (ambient temperature) and the autogenous ignition temperature shall be higher than 150 °C.

When tested by the method described in Annex A, three samples of the lining shall remain in the apparatus at a constant temperature of 360 °C to 365 °C for 2 min without ignition.

If more than one of the samples show evidence of ignition in less than 2 min, the hose shall be considered not to comply. If only one sample shows evidence of ignition in less than 2 min, three further samples shall be prepared and tested. If any of the three samples in this second series shows evidence of ignition in less than 2 min, the hose shall be deemed not to comply.

9.3.2 Resistance to acetone and dimethylformamide

A sample of the lining, when immersed in the acetone or dimethylformamide at standard laboratory temperature as defined in ISO 23529 for 70 h, shall not increase in mass by more than 8 % when calculated in accordance with the method specified in ISO 1817.

9.3.3 Resistance to *n*-pentane

A sample of the hose lining, when tested as described in Annex B, shall show absorbed *n*-pentane not exceeding 15 % mass fraction and *n*-pentane extractable matter not exceeding 10 % mass fraction.

9.3.4 Resistance to azeotrope of trimethylborate with methanol for flux fuel gas hoses

9.3.4.1 Adhesion after conditioning in trimethylborate-methanol azeotrope

The hose when tested in accordance with the following method shall have a minimum adhesion between the rubber lining and the reinforcement of 1,5 kN/m. The inner plastic layer should be removed for this test.

Seal one end of the test hose and fill the hose with the test fluid and condition for (70 ± 2) h at (23 ± 2) °C. After this period empty the test fluid from the hose and leave for 24 h.

An adhesion test in accordance with ISO 8033:2006 using the type 2 or type 4 test piece shall be carried out on three test specimens taken from the hose after the fluid has been removed.

The adhesion between the rubber lining and the reinforcement shall meet the specified requirements.

9.3.4.2 Tensile strength and elongation at break after conditioning in trimethylborate-methanol azeotrope

The hose when tested in accordance with the following method, shall have a variation in the tensile strength and elongation at break of less than 30 % from the original values obtained under 9.2.1.

Seal one end of the test hose and fill the hose with the test fluid and condition for (70 ± 2) h at (23 ± 2) °C. After this period empty the test fluid from the hose and leave for 24 h.

Tensile strength and elongation at break tests in accordance with ISO 37 shall be carried out on five test specimens of plastic lining cut from a hose after the fluid has been emptied. The measurement shall be carried out 24 h after the emptying of the hose.

The variation of the tensile strength and elongation at break shall meet the specified requirements.

9.3.4.3 Change in mass and volume after immersion in trimethylborate-methanol azeotrope

A mass and volume variation test in accordance with ISO 1817 shall be carried out on three test specimens of plastic lining, cut from a hose and immersed in the test liquid for (70 ± 2) h at (23 ± 2) °C.

The mass and volume variation of the plastic lining shall not exceed 8 %. The measurement shall be carried out within 30 min after taking the test pieces out of the test liquid.

9.3.5 Flexibility of flux fuel gas hoses

One sample of hose shall be filled with trimethylborate-methanol azeotrope for 70 h at 23 °C. The flux fuel gas hoses shall then be submitted to the same test as specified in 9.2.5. The test shall be carried out within 30 min after the emptying of the hose. In addition to the requirements of 9.2.5, the hose shall show no signs of leaks when subjected to the proof pressure (carried out at ambient temperature) specified in Table 3.

9.3.6 Permeability to LPG, MPS, and natural gas of methane hoses, universal fuel gas hoses, and flux fuel gas hoses

When tested in accordance with ISO 4080 using a test gas of 95 % volume fraction propylene at cylinder pressure [approximately 0,6 MPa (6 bar)] and standard laboratory temperature of 23 °C as defined in ISO 23529, the gas permeance shall not exceed 25 $cm^3/m \cdot h$, irrespective of internal diameter.

9.3.7 Requirements for twin hoses

9.3.7.1 General

Both of the hoses from the twin hose construction shall after separation by the following test method, conform to this International Standard. Each individual hose shall meet all the requirements when subjected to the relevant tests for the specific hose type.

9.3.7.2 Separation test for twin hose

It shall be possible to separate twin hose into two single hoses with a force between 25 N to 100 N. The test shall be carried out using a tensile test machine. Initially separate using a knife, a sufficient length of the twin hose to enable each individual hose to be secured in the jaws. Mark 200 mm of unseparated hose. Start the test with a jaw separation speed of 100 mm/min. The value of the force to be taken into account is the mean value measured during the propagation phase of the notch, excluding the beginning of the curve.

9.3.8 Requirements for universal fuel gas hose

Hoses shall comply with the requirements of 9.3.2, 9.3.3 and 9.3.6.

10 Hose colour and gas identification

10.1 General

The hose cover material shall be coloured throughout and marked as follows.

10.2 Gas identification

In order to identify the gas for which the hose is to be used, the hose cover shall be coloured and marked as specified in Table 4. In some countries, national requirements on colour identification have been standardized. In these cases, the colour identification detailed in Annex E shall apply. For countries that have no such standards or regulations, the colour identification specified in Table 4 shall apply.

In the case of twin hoses, each of the individual hoses shall be coloured and marked in accordance with this International Standard.

Table 4 — Hose colour and gas identification

Gas	Colour and marking of cover
Acetylene, other combustible gases[a] (except LPG, MPS, natural gas, methane)	red
Oxygen	blue
Compressed-air, nitrogen, argon, CO_2	black
LPG, MPS, natural gas, methane	orange
Universal fuel gases (included in this table) except fluxed fuel gases	red/orange
Fluxed fuel gases	red-FLUX

[a] The manufacturer shall be consulted on the suitability of the hose for use with hydrogen.

10.3 Marking

The hose cover shall be durably marked at least every 1 000 mm with the following information:

— the number of this International Standard: ISO 3821;

— "FLUX" (for flux fuel gas hoses only);

— the maximum working pressure in megapascals and between parentheses in bar;

— the nominal bore;

— the manufacturer's and/or supplier's mark (in the examples given as XYZ);

— the year of manufacture.

EXAMPLE 1 ISO 3821 - 2 MPa (20 bar) - 10 - XYZ - 08

EXAMPLE 2 ISO 3821 - FLUX 2 MPa (20 bar) - 6,3 - XYZ - 08.

Annex A
(normative)

Method of test for non-ignition

A.1 Apparatus

Usual laboratory apparatus and in particular the following.

A.1.1 Apparatus shown in Figure A.1, the tubing portions of which shall be constructed from borosilicate glass of wall thickness:

a) 0,75 mm to 1,25 mm for a diameter of 6 mm to 9 mm;

b) 1 mm to 2 mm for a diameter of 36 mm to 46 mm.

A.1.2 Heating furnace: 350 W, internal dimensions: 150 mm deep by 50 mm diameter.

A.1.3 Tubular variable resistance: 190 Ω to 200 Ω, with screw movement or an auto-transformer with continuously variable output voltage.

A.1.4 Calibrated flowmeter for oxygen: 0 l/min to 5 l/min at atmospheric pressure and 15 °C;

A.1.5 Nitrogen-filled mercury-in-glass thermometer: suitable for use at 150 mm immersion, graduated from approximately 300 °C to 400 °C in intervals of not more than 5 °C, the graduations to start not less than 200 mm above the bulb.

A.2 Procedure

Insert the ignition test apparatus, in its aluminium foil wrapping, into the electric furnace. The purpose of the aluminium foil is to minimize heat loss by radiation and to obtain a more uniform temperature distribution. Adjust the energy supply to the electric furnace with the variable resistance or auto-transformer so that a constant temperature of 360 °C to 365 °C is maintained with the oxygen flowing at (2 ± 0,1) l/min.

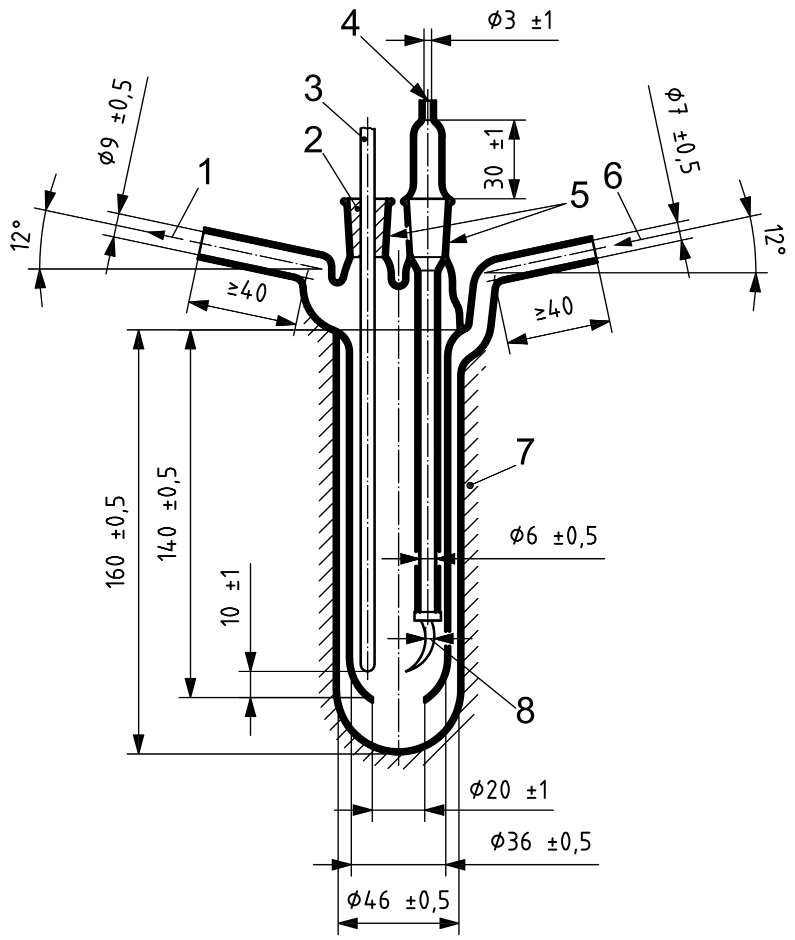
Cut the sample of rubber lining for test, after cleaning by buffing, into blocks of 8 mm^3 to 10 mm^3 of which no side shall be less than 1,3 mm nor greater than 2,5 mm.

When the furnace is at constant temperature, remove the sample holder, impale a sample block of the rubber lining under test on the tungsten point and replace the sample holder in the apparatus. It is necessary for this operation to be carried out quickly, so that cooling is reduced to a minimum. The tungsten point should be kept clean and sharp.

Retain the sample in the apparatus for at least 2 min and observe it carefully during this period for evidence of ignition. Fumes can be observed, but this shall not constitute evidence of ignition, which is normally accompanied by a flash and sometimes by a small explosion. When ignition of a sample occurs, the temperature of the apparatus can rise; time shall then be allowed to permit the temperature to return to the appropriate testing temperature.

Test three samples consecutively.

Dimensions in millimetres



Key

1 oxygen outlet
2 heat-resistant packing
3 thermometer
4 orifice
5 14/23 joints
6 oxygen inlet
7 aluminium foil
8 tungsten wire of diameter 0,7 mm tapered to a fine point and of length (20 ± 0,5) mm

Figure A.1 — Apparatus for ignition tests on lining samples

Annex B
(normative)

Method of test for resistance to *n*-pentane

B.1 Weigh a portion of the hose lining and then immerse it in *n*-pentane at standard laboratory temperature as defined in ISO 23529 for 72 h. The volume of the *n*-pentane shall be at least 50 times the volume of the test piece.

B.2 Following immersion, reweigh the test piece after 5 min conditioning in air at room temperature and reweigh again after 24 h further conditioning under these conditions.

B.3 Calculate the percentage mass fraction *n*-pentane absorbed from Formula (B.1):

$$\frac{m_1 - m_2}{m_0} \times 100 \qquad \text{(B.1)}$$

and the percentage mass fraction of *n*-pentane-extractable matter from Formula (B.2):

$$\frac{m_0 - m_2}{m_0} \times 100 \qquad \text{(B.2)}$$

where

m_0 is the initial mass, in grams, of the test piece;

m_1 is the mass, in grams, of the test piece after immersion and 5 min conditioning;

m_2 is the mass, in grams, of the test piece after 24 h further conditioning.

Annex C
(normative)

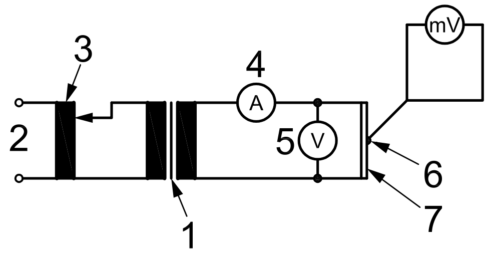
Method of test for resistance to incandescent particles and hot surfaces

A circuit diagram for the chromium-nickel steel heating wire is shown in Figure C.1.

Clamp a sample of hose, approximately 500 mm in length, in the test apparatus (see Figure C.2). Clamp the heating wire (2,5 mm diameter) between the electrical connections, spaced 100 mm apart. The downward force of the incandescent wire, perpendicular to the hose axis, shall be 1 N during the duration of the test (see Figure C.3). During the test, fill the hose with an inert gas, e.g. nitrogen, at a pressure of 0,1 MPa (1 bar). In the case of twin hoses, the force shall be applied straight on the separation line.

Heat the wire with a current of 50 A, at a potential of 2 V max., to obtain a temperature of approximately 800 °C.

If the first test fails, the two subsequent tests shall be satisfactory in order to comply with this annex.



Key

1 isolation transformer

2 power supply

3 variable output transformer

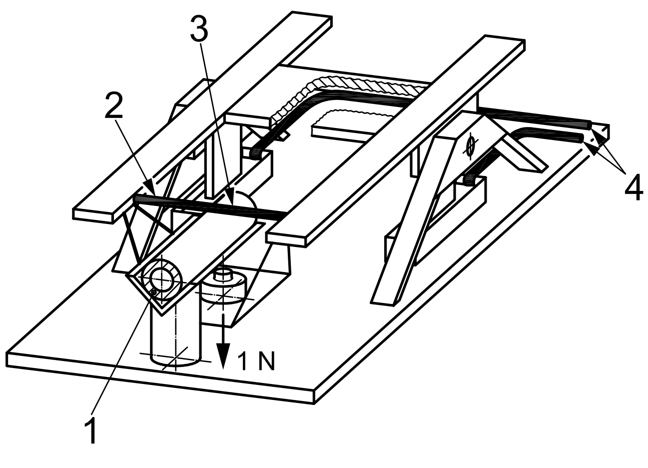
4 ammeter

5 voltmeter

6 thermocouple

7 chromium-nickel steel wire of diameter 2,5 mm

Figure C.1 — Circuit diagram for the test apparatus



Key

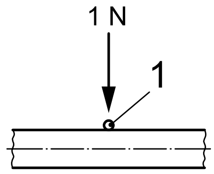
1 flexible hose pressurized to 0,1 MPa (1 bar) excess pressure

2 chromium-nickel steel wire of diameter 2,5 mm

3 thermocouple

4 current conductors

Figure C.2 — Test apparatus



Key

1 chromium-nickel steel wire 18-8

Figure C.3 — Perpendicular force on the hose

Annex D
(normative)

Summary of requirements and type tests

Type testing is carried out by the manufacturer supplying evidence that all requirements of this International Standard are met by their methods of manufacture and hose design. The tests shall be repeated at a maximum interval of 5 years, or whenever a change in the method of manufacture or materials occurs. Table D.1 summarizes the requirements and the tests to be carried out, with the corresponding number of samples, depending on the colour coding and marking of the hoses.

Table D.1 — Summary of requirements and tests with the corresponding number of samples

	Clause	Colour coding and marking						No. samples
		Red - FLUX	Red	Blue	Black	Orange	Red/orange	
Tensile strength and elongation at break	9.2.1	x	x	x	x	x	x	5
Accelerated ageing	9.2.2	x	x	x	x	x	x	5
Non-ignition for oxygen hoses	9.3.1			x				3 (+ 3 [a]) according to Annex A or 1 according to ISO 11114-3
Resistance to acetone and dimethylformamide	9.3.2	x	x				x	3
Resistance to *n*-pentane	9.3.3	x				x	x	3
Resistance to trimethylborate-methanol azeotrope for fluxed fuel gas	9.3.4	x						3 for adhesion reinforcement/lining; + 3 for mass and volume; + 5 for tensile strength
Hydrostatic requirements	9.2.4	x	x	x	x	x	x	1
Adhesion	9.2.3	x	x	x	x	x	x	3 for reinforcement/cover; + 3 for reinforcement/lining
Flexibility, general	9.2.5	x	x	x	x	x	x	1
Flexibility for fluxed fuel gas	9.3.5	x						1
Low-temperature flexibility	9.2.6	x	x	x	x	x	x	1
Resistance to incandescent particles and hot surfaces	9.2.7	x	x	x	x	x	x	1 (+ 2[a])
Ozone resistance	9.2.8	x	x	x	x	x	x	2
Permeability to gas	9.3.6	x				x	x	1
Marking	10.3	x	x	x	x	x	x	1

[a] If necessary, see relevant subclause.

Annex E
(normative)

Alternative oxygen gas colour codes

Table E.1 specifies alternative oxygen gas colour codes for the case where a country has colour identification in their national requirements other than blue, see Clause 10.

Table E.1 — Alternative oxygen gas colour codes

Country	National standard/regulation	Colour
USA	CGA E-5 UL 123	Green

Bibliography

[1] ISO 3, *Preferred numbers — Series of preferred numbers*

ICS 25.160.30; 83.140.40
Price based on 16 pages