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Gas cylinders — Compatibility of cylinder and valve materials with gas contents —

Part 1: Metallic materials

Bouteilles à gaz — Compatibilité des matériaux des bouteilles et des robinets avec les contenus gazeux —

Partie 1: Matériaux métalliques

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of 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 www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 58, *Gas cylinders*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 23, *Transportable gas cylinders*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This third edition cancels and replaces the second edition (ISO 11114-1:2012), which has been technically revised. It also incorporates the Amendment ISO 11114-1:2012/Amd.1:2017. The main changes compared to the previous edition are as follows:

— inclusion of all changes in ISO 11114-1:2012/Amd.1:2017;

— clarification of the definition of dry;

— addition of notes in Table 1.

A list of all parts in the ISO 11114 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Industrial, medical and special gases (e.g. high-purity gases, calibration gases) can be transported or stored in gas cylinders. An essential requirement of the material from which such gas cylinders and their valves are manufactured is compatibility with the gas content.

Compatibility of cylinder materials with gas content has been established over many years by practical application and experience. Existing national and international regulations and standards do not fully cover this aspect.

This document is based on current international experience and knowledge.

This document has been written so that it is suitable to be referenced in the UN Model Regulations[1].

Gas cylinders — Compatibility of cylinder and valve materials with gas contents —

Part 1: Metallic materials

1 Scope

This document provides requirements for the selection of safe combinations of metallic cylinder and valve materials and cylinder gas content.

The compatibility data given is related to single gases and to gas mixtures.

Seamless metallic, welded metallic and composite gas cylinders and their valves, used to contain compressed, liquefied and dissolved gases are considered.

NOTE In this document the term "cylinder" refers to transportable pressure receptacles, which also include tubes and pressure drums.

Aspects such as the quality of delivered gas product are not considered.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 10156, *Gas cylinders — Gases and gas mixtures — Determination of fire potential and oxidizing ability for the selection of cylinder valve outlets*

ISO 10286, *Gas cylinders — Terminology*

ISO 10297, *Gas cylinders — Cylinder valves — Specification and type testing*

ISO 11114-2, *Gas cylinders — Compatibility of cylinder and valve materials with gas contents — Part 2: Non-metallic materials*

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 10286 and the following apply.

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

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
competent person
person who has the necessary technical knowledge, experience and authority to assess and approve materials for use with gases and to define any special conditions of use that are necessary

3.2
acceptable
A
material/gas combination that is safe under normal conditions of use, provided that any indicated non-compatibility risks are taken into account

Note 1 to entry: Low levels of impurities can affect the acceptability of some single gases or gas mixtures.

3.3
not acceptable
N
material/single gas combination that is not safe under all normal conditions of use

Note 1 to entry: For gas mixtures special conditions may apply (see 6.2 and Table 1).

3.4
dry
state in which there is no free water in a cylinder under any service conditions, including at the highest expected operating pressure and at the lowest expected operating temperature

Note 1 to entry: For compressed gases at, for example, 200 bar and –20 °C, the maximum moisture content is not to exceed 5 ppmV, to avoid condensation of free water. For other temperatures and pressures, the maximum moisture content needed to avoid condensation of water will be different. Another source of moisture to be considered is the cylinder itself which implies appropriate drying procedures such as purging and vacuuming.

3.5
wet
state in which the conditions as defined for *dry* (3.4) are not met

3.6
gas mixture
combination of different single gases deliberately mixed in specified proportions

3.7
single gas
gas which does not contain deliberately added content of another gas or gases

4 Materials

4.1 General

The compatibility of most materials used to manufacture gas cylinders and valves is identified in this document.

Other materials whose compatibility is not identified in this document may be used if all compatibility aspects have been considered and validated by a competent person.

4.2 Cylinder materials

The most commonly used metallic materials for cylinders are (among others) carbon manganese steel, chromium molybdenum steel, chromium molybdenum nickel steel, stainless steel and aluminium alloys, as specified in the following documents:

— aluminium and aluminium alloys: ISO 6361-2, ISO 7866 and ISO 11118;

— steel: ISO 4706, ISO 9328-5, ISO 9809-1, ISO 9809-2, ISO 9809-3, ISO 11118 and ISO 11120;

— stainless steel: ISO 9809-4 and ISO 15510.

4.3 Valve materials

4.3.1 General

The most commonly used metallic materials for valve bodies and internal gas wetted parts are brass and other similar copper-based alloys, carbon steel, stainless steel, refined nickel and nickel alloys, Cu–Be (2 %) and aluminium alloys.

4.3.2 Particular considerations

4.3.2.1 In special cases, non-compatible materials may be used for non-oxidizing gases if suitably plated, protected or coated. This may only be done if all compatibility aspects have been considered and validated by a competent person for the entire life of the valve.

4.3.2.2 Special precautions, in accordance with ISO 11114-3 (which addresses testing, not precautions per se), shall be taken for oxidizing gases as specified in ISO 10156. In this case, non-compatible materials are *not acceptable* (see 3.3) for use in valves, even if plated, protected or coated.

4.3.2.3 For cylinder valves, compatibility in wet conditions shall be considered because of the high risk of contamination by atmospheric moisture and an airborne contaminant.

NOTE Reference is made in this document to stainless steels by their commonly used AISI identification numbers, i.e. 304. For example, the equivalent grades according to EN 10088-1 are as follows:

304	1.4301
304L	1.4306 and 1.4307
316	1.4401
316L	1.4404
316Ti	1.4571
321	1.4541
904L	1.4539

5 Compatibility criteria

5.1 General

Compatibility between a gas and the cylinder/valve material is affected by chemical reactions and physical influences, which can be classified into five categories:

— corrosion;

— stress corrosion cracking;

— hydrogen embrittlement;

— generation of dangerous products through chemical reaction;

— violent reactions, such as ignition.

Non-metallic components (valve sealing, gland packing, O-ring, etc.) shall be in accordance with ISO 11114-2.

Sealing or lubricating materials (when used) at the valve stem shall be compatible with the gas content.

NOTE Annex A gives the gas/materials NQSAB compatibility codes, for information.

5.2 Corrosion

5.2.1 General

Many types of corrosion mechanisms can occur due to the presence of the gas, as outlined in 5.2.2 to 5.2.4.

5.2.2 Corrosion in dry conditions

This corrosion is affected by chemical attack by a dry gas on the cylinder material. The result is a reduction of the cylinder wall thickness. This type of corrosion is not very common, because the rate of dry corrosion is very low at ambient temperature.

5.2.3 Corrosion in wet conditions

This is the most common type of corrosion, which only occurs in a gas cylinder due to the presence of free water or aqueous solutions. However, with some hygroscopic gases (e.g. HCl, Cl_2) corrosion would occur even if the water content were less than the saturation value. Therefore, some gas/material combinations are not recommended, even if inert in the theoretical dry conditions. It is thus very important to prevent any water ingress into gas cylinders. The most common sources of or reasons for water ingress are:

a) the customer, by retro-diffusion/backfilling or when the cylinder is empty, by air entry, if the valve is not closed,

b) ineffective drying following hydraulic testing, and

c) during filling.

In some cases, it is very difficult to completely prevent water ingress – particularly when the gas is hygroscopic (e.g. HCl, Cl_2). In cases where the filler cannot guarantee the dryness of gas and cylinder, a cylinder material which is compatible with the wet gas shall be used, even if the dry gas is not corrosive.

There are several different types of "wet corrosion" in alloys:

1) general corrosion leading to the reduction of the wall thickness, e.g. by acid gases (CO_2, SO_2) or oxidizing gases (O_2, Cl_2);

2) localized corrosion, e.g. pitting corrosion or grain boundary attack.

Additionally, some gases, even inert ones, when hydrolysed could lead to the production of corrosive products.

5.2.4 Corrosion by impurities

Gases which themselves are inert (non-corrosive) can cause corrosion due to the presence of impurities. Contamination of gases can occur, during filling, during use or if the initial product is not properly purified.

The most common pollutants are:

a) atmospheric air, in which case the harmful impurities can be moisture (see also 5.2.3) and oxygen (e.g. in liquefied ammonia);

b) aggressive products contained in some gases, e.g. H_2S in natural gas;

c) aggressive traces (acid, mercury, etc.) remaining from the manufacturing process of some gases.

The materials compatible with the impurities shall be used if the presence of these impurities cannot be prevented and if the corresponding corrosion rate is unacceptable for the intended application.

5.3 Hydrogen embrittlement phenomenon

Embrittlement caused by hydrogen can occur at ambient temperature in the case of certain gases and under service conditions which stress the cylinder or valve material.

This type of stress cracking phenomenon can, under certain conditions, lead to the failure of gas cylinders and/or valve components containing hydrogen, mixtures of hydrogen and other gases.

5.4 Generation of dangerous products

In some cases, reactions of a gas with a metallic material can lead to the generation of dangerous products. Examples are the possible reactions of C_2H_2 with copper alloys containing more than 65 % copper and of CH_3Cl in aluminium alloy cylinders.

5.5 Violent reactions (e.g. ignition)

In principle, violent reactions of gas/metallic material are not very common at ambient temperatures, because high activation energies are necessary to initiate such reactions. In the case where a combination of non-metallic and metallic materials is used, e.g. for valves, this type of reaction can occur with some gases (e.g. O_2, Cl_2).

5.6 Stress corrosion cracking

Stress corrosion cracking can occur in many metallic materials subjected to stress, moisture and a contaminant at the same time. Stress corrosion cracking can, under certain conditions, lead to the failure of the gas cylinder or valve and/or its components (e.g. ammonia in contact with copper alloy valves or carbon monoxide/carbon dioxide mixtures in steel cylinders).

6 Material compatibility

6.1 Table of compatibility for single gases

Before any gas/cylinder/valve combination is chosen a careful study of all the *key compatibility characteristics* given in Table 1 shall be made. Particular attention shall be paid to any restrictions, which shall be applied to acceptable materials.

NOTE The gases are generally listed in the table in English alphabetical order.

6.2 Compatibility for gas mixtures

Any gas mixtures containing single gases that are all compatible with a given material shall be considered as being compatible with this material.

For gas mixtures containing gases causing embrittlement (see 5.3, and Clause A.4, groups 2 and 11) the risk of hydrogen embrittlement only occurs if the partial pressure of the gas is greater than 5 MPa (50 bar) and the stress level of the cylinder material is high enough. In a gas mixture, the partial pressure for hydrogen sulphide and methyl mercaptan shall be less than 0,25 MPa (2,5 bar) at a maximum UTS (ultimate tensile strength) of 950 MPa. If the stress level of the cylinder material is high, see Table 1, row 63.

Some International Standards, such as ISO 11114-4, specify test methods for selecting appropriate steels with a maximum UTS greater than 950 MPa.

For the halogenated gases that are not compatible with aluminium alloy cylinders, the maximum acceptable concentration in gas mixtures shall be limited to 0,1 % as indicated in Table 1 unless higher concentrations have been validated after conducting specific tests (examples of such tests are given in EIGA document 161/16[14]). The moisture content (dryness) in these mixtures shall be limited to a maximum of 10 ppmV.

For non-compatibility of some halogenated gases with aluminium alloys, the maximum acceptable content is given in Table 1. The level of moisture can affect the acceptability of such mixtures.

6.3 Using Table 1

6.3.1 Conventions and numbers

In Table 1, **bold face** type indicates that the material is commonly used under normal service conditions:

— A = acceptable (see 3.2);

— N = not acceptable (see 3.3).

If there is no UN number listed for a gas (or liquid), the gas has no official UN number but may be shipped using a generic NOS (not otherwise specified) number.

EXAMPLE UN 1954, Compressed gas, flammable, N.O.S.

6.3.2 Abbreviations for materials

CS carbon steels used for the manufacture of cylinder valve bodies

NS carbon steels heat treated by normalization that are used for the manufacture of seamless and welded cylinders

QTS alloy steels that are treated by quenching and tempering and that are used for the manufacture of seamless steel cylinders

SS austenitic type stainless steels used for the manufacture of seamless and welded cylinders and some valve bodies and valve components

AA aluminium alloys specified in ISO 7866 when used for the manufacture of seamless cylinders; for aluminium valve bodies, alloys not specified in ISO 7866 may also be used

B brass and other copper alloys used for the manufacture of cylinder valves

Ni nickel alloys used for the manufacture of cylinders, valves and valve components

Cu copper

ASB aluminium silicon bronze

Table 1 — Gas/material compatibility

No.	Gas number UN number	Name	Formula	Key compatibility characteristics	Material			
					Cylinder		Valve (body and components)	
					A	N	A	N
1	(UN 1001) (UN 3374)	ACETYLENE	C_2H_2	Ability to form explosive acetylides with certain metals, including copper and copper alloys. Use <65 % Cu and copper alloy. This also applies to mixtures of more than 1 % C_2H_2. The acceptable limit of the silver content of alloys should preferably be 43 % (by mass) but in no case exceeding 50 %. There is no known incompatibility between the solvents used and any metallic materials, this is more relevant for ISO 11114-2.	**NS** QTS AA SS Ni		**B** CS AA SS Ni	B (Cu >65 %) Cu-Be (2 %)
2	(UN 1005)	AMMONIA	NH_3	Risk of stress corrosion cracking with brass (and other copper alloys) valves due to atmospheric contaminant. This applies to all gases and mixtures containing even traces of NH_3.	**NS** QTS AA SS Ni		**CS** SS AA Ni	B
3	(UN 1006)	ARGON	Ar	No reaction with any common materials in dry or wet conditions.	**NS** **QTS** **AA** SS		**B** CS SS AA	

[a] Brass is only acceptable as a valve body but not as a general valve component material.

[b] For mixtures containing up to 1 000 ppm of dry NO, brass valves can be used.

Table 1 *(continued)*

No.	Gas number UN number	Name	Formula	Key compatibility characteristics	Material			
					Cylinder		Valve (body and components)	
					A	N	A	N
4	(UN 2188)	ARSINE	AsH_3	Because of risk of hydrogen embrittlement: — QTS are limited to a maximum ultimate tensile strength of 950 MPa; — SS may be used for valve diaphragms and springs when there is operating experience that shows the design is suitable and safe. Alternatively, use is also authorized if failure of the SS springs or SS diaphragms does not result in an unsafe condition. NOTE Some SS alloys can be sensitive to hydrogen embrittlement. See special conditions for mixtures given in 6.2.	**NS** **QTS** **AA** SS		**B** CS **SS** AA Ni	
5	(UN 1741)	BORON TRICHLORIDE	BCl_3	Hydrolyses to hydrogen chloride in contact with moisture. In wet conditions, see specific risk of hydrogen chloride compatibility, i.e. severe corrosion of most of the materials and risk of hydrogen embrittlement. Mixtures of dry gas not exceeding 0,1 % of this gas may be filled into AA cylinders.	**NS** **QTS** SS Ni	AA	CS SS **Ni**	AA B
6	(UN 1008)	BORON TRIFLUORIDE	BF_3	Hydrolyses to hydrogen fluoride in contact with moisture. In wet conditions, see specific risk of hydrogen fluoride compatibility, i.e. severe corrosion of most of the materials and risk of hydrogen embrittlement. Mixtures containing less than 0,1 % BF_3 may be filled into AA cylinders.	**NS** **QTS** SS Ni	AA	CS SS **Ni**	AA B

[a] Brass is only acceptable as a valve body but not as a general valve component material.

[b] For mixtures containing up to 1 000 ppm of dry NO, brass valves can be used.

Table 1 *(continued)*

No.	Gas number UN number	Name	Formula	Key compatibility characteristics	Material			
					Cylinder		Valve (body and components)	
					A	N	A	N
7	(UN 1974)	BROMOCHLORODIFLUORO-METHANE	$CBrClF_2$ (R12B1)	No reaction with any common materials when dry but in the presence of free water, corrosion can occur.	NS QTS AA SS		B CS SS AA	
8	(UN 1009)	BROMOTRIFLUOROMETHANE	$CBrF_3$ (R13B1)	No reaction with any common materials when dry but in the presence of free water, corrosion can occur.	**NS** **QTS** AA SS		**B** CS SS AA	
9	(UN 2419)	BROMOTRIFLUOROETHYLENE	C_2BrF_3	No reaction with any common materials when dry but in the presence of free water, corrosion can occur.	**NS** **QTS** AA SS		**B** CS SS AA	
10	(UN 1010)	BUTADIENE-1,3	$H_2C{:}CHCH{:}CH_2$	No reaction with any common materials. See 5.2.4 for the effect of impurities in wet conditions.	**NS** QTS AA SS		**B** CS SS AA	
11	(UN 1010)	BUTADIENE-1,2	$H_2C{:}C{:}CHCH_3$	No reaction with any common materials. See 5.2.4 for the effect of impurities in wet conditions.	**NS** QTS AA SS		**B** CS SS AA	
12	(UN 1011)	BUTANE	C_4H_{10}	No reaction with any common materials. See 5.2.4 for the effect of impurities in wet conditions.	**NS** QTS AA SS		**B** CS SS AA	

[a] Brass is only acceptable as a valve body but not as a general valve component material.

[b] For mixtures containing up to 1 000 ppm of dry NO, brass valves can be used.

Table 1 *(continued)*

No.	Gas number UN number	Name	Formula	Key compatibility characteristics	Material			
					Cylinder		Valve (body and components)	
					A	N	A	N
13	(UN 1012)	BUTENE-1	$CH_3CH_2CH{:}CH_2$	No reaction with any common materials. See 5.2.4 for the effect of impurities in wet conditions.	**NS** QTS AA SS		**B** CS SS AA	
14	(UN 1012)	BUTENE-2 (CIS)	$CH_3CH{:}CHCH_3$	No reaction with any common materials. See 5.2.4 for the effect of impurities in wet conditions.	**NS** QTS AA SS		**B** CS SS AA	
15	(UN 1012)	BUTENE-2 (TRANS)	$CH_3CH{:}CHCH_3$	No reaction with any common materials. See 5.2.4 for the effect of impurities in wet conditions.	**NS** QTS AA SS		**B** CS SS AA	
16	(UN 1013)	CARBON DIOXIDE	CO_2	No reaction with any common materials when dry. Forms acidic carbonic in the presence of free water; corrosive for NS, QTS and CS. Risk (for NS and QTS) of stress corrosion cracking in presence of CO (see carbon monoxide) and water.	**NS** **QTS** **AA** SS		**B** CS SS AA	

[a] Brass is only acceptable as a valve body but not as a general valve component material.

[b] For mixtures containing up to 1 000 ppm of dry NO, brass valves can be used.

Table 1 *(continued)*

No.	Gas number UN number	Name	Formula	Key compatibility characteristics	Material			
					Cylinder		Valve (body and components)	
					A	N	A	N
17	(UN 1016)	CARBON MONOXIDE	CO	Risk of formation of toxic metal carbonyls. Highly sensitive to any traces of moisture [>5 ppmV at 20 MPa (200 bar)], in the presence of CO_2 (>5 ppmV). Industrial grades of carbon monoxide normally contain traces of CO_2. This can result in risk of stress corrosion cracking, in the case of QTS, CS and NS cylinders if used at the normal service stress levels. Experience shows that this risk is eliminated if the fill pressure at 15 °C is less than 50 % of the cylinder working pressure. For details, see EIGA/CGA reference in the Bibliography. For QTS, CS, and NS steels this risk of stress corrosion cracking shall be considered for mixtures containing down to 0,1 % CO. Refined nickel gaskets used for some applications are not compatible with CO. NOTE AA and SS are not affected by this stress corrosion cracking phenomenon. Nickel alloys also suffer from a high propensity to form carbonyls. Alloys with less than 50% Nickel, such as the Incoloy©[1] may be acceptable[16].	**NS** **QTS** **AA** SS		**B** CS SS AA	
18	(UN 1982)	TETRAFLUORMETHANE (CARBON TETRAFLUORIDE)	CF_4 (R14)	No reaction with any common materials when dry but in the presence of free water, corrosion can occur.	**NS** **QTS** AA SS		**B** CS SS AA	

[a] Brass is only acceptable as a valve body but not as a general valve component material.

[b] For mixtures containing up to 1 000 ppm of dry NO, brass valves can be used.

Table 1 *(continued)*

No.	Gas number UN number	Name	Formula	Key compatibility characteristics	Material			
					Cylinder		Valve (body and components)	
					A	N	A	N
19	(UN 2204)	CARBONYL SULPHIDE	COS	Risk of formation of toxic metal carbonyls at temperature >100 °C. Highly sensitive to any traces of moisture (>5 ppmV), in the presence of CO_2 (>5 ppmV); industrial grades of carbonyl sulphide normally contain traces of CO_2. This results in a risk of stress corrosion cracking, in the case of QTS, NS and CS. See also CO (No.17).	NS **QTS** **AA** SS		B CS SS AA	
20	(UN 1017)	CHLORINE	Cl_2	Hydrolyses to hypochlorous acid and to hydrogen chloride in contact with moisture. In wet conditions, see specific risk of hydrogen chloride compatibility, i.e. severe corrosion of most of the materials and risk of hydrogen embrittlement. The service life of brass valves strongly depends on the operating service conditions. Mixtures containing less than 0,1 % of this gas may be filled into AA cylinders.	**NS** QTS SS	AA	**CS** B[a] SS Ni ASB	AA
21	(UN 1018)	CHLORODIFLUOROMETHANE	$CHClF_2$ (R22)	No reaction with any common materials when dry, but in the presence of free water corrosion occurs.	**NS** **QTS** AA SS		**B** CS SS AA ASB	
22	(UN 1063)	METHYL CHLORIDE	CH_3Cl (R40)	In the presence of free water, corrosion can occur. Mixtures of dry gas containing not more than 0,1 % of this gas may be filled into AA cylinders. No reaction with any common materials when dry, but in the presence of free water corrosion occurs.	**NS** **QTS** SS Ni	AA	**B** CS SS Ni	AA

[a] Brass is only acceptable as a valve body but not as a general valve component material.

[b] For mixtures containing up to 1 000 ppm of dry NO, brass valves can be used.

Table 1 *(continued)*

No.	Gas number UN number	Name	Formula	Key compatibility characteristics	Material			
					Cylinder		Valve (body and components)	
					A	N	A	N
23	(UN 1020)	CHLOROPENTAFLUOROETHANE	C_2ClF_5 (R115)	No reaction with any common materials when dry, but in the presence of free water corrosion occurs.	**NS** **QTS** AA SS		**B** CS SS AA	
24	(UN 1021)	CHLOROTETRAFLUOROETHANE	$CClF_2CHF_2$ (R124)	No reaction with any common materials when dry, but in the presence of free water corrosion occurs.	**NS** **QTS** AA SS		**B** CS SS AA	
25	(UN 1983)	CHLOROTRIFLUOROETHANE	CH_2ClCF_3 (R133a)	No reaction with any common materials when dry, but in the presence of free water corrosion occurs.	**NS** **QTS** AA SS		**B** CS SS AA	
26	(UN 1082)	CHLOROTRIFLUOROETHYLENE	C_2ClF_3 (R1113)	No reaction with any common materials when dry, but in the presence of free water corrosion occurs.	**NS** **QTS** AA SS		**B** CS SS AA	
27	(UN 1022)	CHLOROTRIFLUOROMETHANE	$CClF_3$ (R13)	No reaction with any common materials when dry, but in the presence of free water corrosion occurs.	**NS** **QTS** AA SS		**B** CS SS AA	
28	(UN 1027)	CYCLOPROPANE	C_3H_6	No reaction with any common materials.	**NS** **QTS** AA SS		**B** CS SS AA	

[a] Brass is only acceptable as a valve body but not as a general valve component material.

[b] For mixtures containing up to 1 000 ppm of dry NO, brass valves can be used.

Table 1 *(continued)*

No.	Gas number UN number	Name	Formula	Key compatibility characteristics	Material			
					Cylinder		Valve (body and components)	
					A	N	A	N
29	(UN 1957)	DEUTERIUM	D_2	Because of risk of hydrogen embrittlement: — QTS are limited to a maximum ultimate tensile strength of 950 MPa; — SS may be used for valve diaphragms and springs when there is operating experience that shows the design is suitable and safe. Alternatively, use is also authorized if failure of the SS springs or SS diaphragms does not result in an unsafe condition. NOTE Some SS alloys can be sensitive to hydrogen embrittlement. See special conditions for mixtures given in 6.2. Refined nickel is not acceptable for bursting disks and other components. Risk of embrittlement due to the presence of mercury from certain production processes has to be considered, especially with AA.	**QTS** NS AA SS		**B** CS AA SS	
30	(UN 1941)	DIBROMODIFLUOROMETHANE	CBr_2F_2 (R12B2)	No reaction with any common materials when dry, but in the presence of free water corrosion occurs.	**QTS** NS AA SS		**B** CS AA SS	
31	(See 6.3.1)	DIBROMOTETRAFLUORO-ETHANE	$C_2Br_2F_4$	No reaction with any common materials when dry, but in the presence of free water corrosion occurs.	**QTS** NS AA SS		**B** CS AA SS	

[a] Brass is only acceptable as a valve body but not as a general valve component material.

[b] For mixtures containing up to 1 000 ppm of dry NO, brass valves can be used.

Table 1 *(continued)*

No.	Gas number UN number	Name	Formula	Key compatibility characteristics	Material			
					Cylinder		Valve (body and components)	
					A	N	A	N
32	(UN 1911)	DIBORANE	B_2H_6	Because of risk of hydrogen embrittlement: — QTS are limited to a maximum ultimate tensile strength of 950 MPa; — SS may be used for valve diaphragms and springs when there is operating experience that shows the design is suitable and safe. Alternatively, use is also authorized if failure of the SS springs or SS diaphragms does not result in an unsafe condition. NOTE Some SS alloys can be sensitive to hydrogen embrittlement. See special conditions for mixtures given in 6.2.	**QTS** **NS** AA SS		**B** **SS** CS Ni	
33	(UN 1028)	DICHLORODIFLUOROMETHANE	CCl_2F_2 (R12)	No reaction with any common materials when dry, but in the presence of free water corrosion occurs.	**QTS** NS AA SS		**B** CS AA SS	
34	(UN 1029)	DICHLOROFLUOROMETHANE	$CHCl_2F$ (R21)	No reaction with any common materials when dry, but in the presence of free water corrosion occurs.	**QTS** NS AA SS		**B** CS AA SS	
35	(UN 2189)	DICHLOROSILANE	SiH_2Cl_2	Hydrolyses to hydrogen chloride in contact with moisture. In wet conditions, see specific risk of hydrogen chloride compatibility, i.e. severe corrosion of most materials and risk of hydrogen embrittlement. Mixtures of dry gas not exceeding 0,1 % of this gas may be filled into AA cylinders.	**QTS** **NS** SS Ni	AA	SS CS **Ni**	AA B

[a] Brass is only acceptable as a valve body but not as a general valve component material.

[b] For mixtures containing up to 1 000 ppm of dry NO, brass valves can be used.

Table 1 *(continued)*

No.	Gas number UN number	Name	Formula	Key compatibility characteristics	Material			
					Cylinder		Valve (body and components)	
					A	N	A	N
36	(UN 1958)	DICHLOROTETRA-FLUOROETHANE	$C_2Cl_2F_4$ (R114)	No reaction with any common materials when dry, but in the presence of free water corrosion occurs.	**QTS** **NS** AA SS		**B** CS AA SS	
37	(UN 1026)	CYANOGEN	C_2N_2	In the presence of free water, pitting corrosion can occur. Pitting corrosion can be minimized by using SS alloys such as 316. Risk of stress corrosion cracking with brass (and other copper alloys) due to atmospheric moisture, whatever the concentration.	**NS** QTS AA SS		Ni CS AA SS	B
38	(UN 2517)	1-CHLORO-1,1-DIFLUOROETHANE	CH_3CClF_2 (R142b)	No reaction with any common materials when dry, but in the presence of free water corrosion occurs.	**QTS** **NS** AA SS		**B** CS AA SS	
39	(UN 1030)	1,1-DIFLUOROETHANE	CH_3CHF_2 (R152a)	No reaction with any common materials when dry, but in the presence of free water corrosion occurs.	**QTS** **NS** AA SS		**B** CS AA SS	
40	(UN 1959)	1,1-DIFLUOROETHYLENE	$C_2H_2F_2$ (R1132a)	No reaction with any common materials when dry, but in the presence of free water corrosion occurs.	**QTS** NS AA SS		**B** CS AA SS	
41	(UN 1032)	DIMETHYLAMINE	$(CH_3)_2NH$	Risk of stress corrosion cracking with brass (and other copper alloys) valves due to atmospheric moisture, whatever the concentration.	**QTS** **NS** AA		CS SS AA	B

[a] Brass is only acceptable as a valve body but not as a general valve component material.

[b] For mixtures containing up to 1 000 ppm of dry NO, brass valves can be used.

Table 1 *(continued)*

No.	Gas number UN number	Name	Formula	Key compatibility characteristics	Material			
					Cylinder		Valve (body and components)	
					A	N	A	N
42	(UN 1033)	DIMETHYL ETHER	$(CH_3)_2O$	No reaction with any common materials.	**NS** QTS AA SS		**B** CS AA SS	
43	(see 6.3.1)	DISILANE	Si_2H_6	Because of risk of hydrogen embrittlement: — QTS are limited to a maximum ultimate tensile strength of 950 MPa; — SS may be used for valve diaphragms and springs when there is operating experience that shows the design is suitable and safe. Alternatively, use is also authorized if failure of the SS springs or SS diaphragms does not result in an unsafe condition. NOTE Some SS alloys can be sensitive to hydrogen embrittlement. See special conditions for mixtures given in 6.2.	**NS** **AA** **QTS** SS		**B** CS **SS** AA	
44	(UN 1035)	ETHANE	C_2H_6	No reaction with any common materials.	**QTS** **AA** NS SS		**B** CS AA SS	
45	(UN 1036)	ETHYLAMINE	$C_2H_5NH_2$	Risk of stress corrosion cracking with brass (and other copper alloys) valves due to atmospheric moisture, whatever the concentration.	**QTS** **NS** AA SS		**SS** **CS** AA	B

[a] Brass is only acceptable as a valve body but not as a general valve component material.

[b] For mixtures containing up to 1 000 ppm of dry NO, brass valves can be used.

Table 1 *(continued)*

No.	Gas number UN number	Name	Formula	Key compatibility characteristics	Material			
					Cylinder		Valve (body and components)	
					A	N	A	N
46	(UN 1037)	ETHYL CHLORIDE	C_2H_5Cl (R160)	No reaction with any common materials when dry but in the presence of free water, corrosion can occur. Mixtures of dry gas not exceeding 0,1 % of this gas may be filled into AA cylinders.	**QTS** **NS** SS Ni	AA	**B** **SS** CS Ni	AA
47	(UN 1962)	ETHYLENE	C_2H_4	No reaction with any common materials.	**QTS** **AA** NS SS		**B** CS AA SS	
48	(UN 1040)	ETHYLENE OXIDE	C_2H_4O	Ethylene oxide polymerizes. Ethylene oxide polymerization increases in the presence of moisture, rust and other contaminants. Use dry and clean cylinders. Copper is not acceptable.	**QTS** **NS** AA SS		B CS AA SS	Cu
49	(UN 1045)	FLUORINE	F_2	Hydrolyses to hydrogen fluoride in contact with moisture. In wet conditions, see specific risk of hydrogen fluoride compatibility, i.e. severe corrosion of most of the materials and risk of hydrogen embrittlement. Risk of violent reaction with AA. Recommended materials are also Ni alloy and refined nickel. Mixtures containing less than 0,1 % of this gas may be filled into AA cylinders.	**QTS** **NS** SS Ni	AA	CS SS Ni	AA B[a]
50	(UN 2453)	FLUOROETHANE	C_2H_5F (R161)	No reaction with any common materials when dry, but in the presence of free water corrosion occurs.	**QTS** NS AA SS		**B** CS AA SS	

[a] Brass is only acceptable as a valve body but not as a general valve component material.

[b] For mixtures containing up to 1 000 ppm of dry NO, brass valves can be used.

Table 1 *(continued)*

No.	Gas number UN number	Name	Formula	Key compatibility characteristics	Material			
					Cylinder		Valve (body and components)	
					A	N	A	N
51	(UN 2454)	FLUOROMETHANE	CH_3F (R41)	No reaction with any common materials when dry, but in the presence of free water corrosion occurs.	**QTS** NS AA SS		**B** CS AA SS	
52	(UN 1984)	TRIFLUOROMETHANE	CHF_3 (R23)	No reaction with any common materials when dry, but in the presence of free water corrosion occurs.	**QTS** NS AA SS		**B** CS AA SS	
53	(UN 2192)	GERMANE	GeH_4	Because of risk of hydrogen embrittlement: — QTS are limited to a maximum ultimate tensile strength of 950 MPa; — SS may be used for valve diaphragms and springs when there is operating experience that shows the design is suitable and safe. Alternatively, use is also authorized if failure of the SS springs or SS diaphragms does not result in an unsafe condition. NOTE Some SS alloys can be sensitive to hydrogen embrittlement. See special conditions for mixtures in 6.2.	**QTS** **NS** **AA** SS		**B** CS **SS** AA	
54	(UN 1046)	HELIUM	He	No reaction with any common materials.	NS **QTS** AA SS		**B** CS SS AA	

[a] Brass is only acceptable as a valve body but not as a general valve component material.

[b] For mixtures containing up to 1 000 ppm of dry NO, brass valves can be used.

Table 1 *(continued)*

No.	Gas number UN number	Name	Formula	Key compatibility characteristics	Material			
					Cylinder		Valve (body and components)	
					A	N	A	N
55	(UN 2193)	HEXAFLUOROETHANE	C_2F_6 (R116)	No reaction with any common materials when dry, but in the presence of free water corrosion occurs.	NS **QTS** AA SS		**B** CS SS AA	
56	(UN 1858)	HEXAFLUOROPROPENE	C_3F_6 (R1216)	No reaction with any common materials when dry, but in the presence of free water corrosion occurs.	NS **QTS** AA SS		**B** CS SS AA	
57	(UN 1049)	HYDROGEN	H_2	Because of risk of hydrogen embrittlement: — QTS are limited to a maximum ultimate tensile strength of 950 MPa; — for seamless steel cylinders made to ISO 9809-1 or ISO 11120 from Cr-Mo quenched and tempered steels: unless they are validated by appropriate testing according to ISO 11114-4, and with a hydrogen partial pressure above 5 MPa (50 bar), the maximum UTS of the steel shall not exceed 950 MPa; — SS may be used for valve diaphragms and springs when there is operating experience that shows the design is suitable and safe. Alternatively, use is also authorized if failure of the SS springs or SS diaphragms does not result in an unsafe condition.	NS **QTS** AA SS		**B** CS SS AA Cu-Be (2 %)	

[a] Brass is only acceptable as a valve body but not as a general valve component material.

[b] For mixtures containing up to 1 000 ppm of dry NO, brass valves can be used.

Table 1 *(continued)*

No.	Gas number UN number	Name	Formula	Key compatibility characteristics	Material			
					Cylinder		Valve (body and components)	
					A	N	A	N
				NOTE Some SS alloys are sensitive to hydrogen embrittlement. See special conditions for mixtures given in 6.2. Refined nickel is not acceptable for bursting disks and other components. Risk of embrittlement due to the presence of mercury from certain production processes has to be considered, especially with AA.				
58	(UN 1048)	HYDROGEN BROMIDE	HBr	This compound is highly hygroscopic and corrosive in wet conditions with most of the materials except some high corrosion resistant nickel alloys (e.g. Hastelloy C). QTS are limited to a maximum ultimate tensile strength of 950 MPa. This limitation also applies to mixtures containing the gas stored at a total pressure at 15 °C greater than half the normal service pressure of the cylinder. However, experience shows that a cylinder can be safely used without any specific strength limitation requirements, providing the maximum working pressure at 15 °C in the cylinder is less than one-fifth of the test pressure (TP/5), in order to maintain a low stress level in the cylinder material. SS shall not be used for valve diaphragms or springs except if the failure of such components does not result in an unsafe situation. Mixtures of dry gas not exceeding 0,1 % of this gas may be filled into AA cylinders.	**NS** **QTS** SS Ni	AA	CS **SS** **Ni**	B AA

[a] Brass is only acceptable as a valve body but not as a general valve component material.

[b] For mixtures containing up to 1 000 ppm of dry NO, brass valves can be used.

Table 1 *(continued)*

No.	Gas number UN number	Name	Formula	Key compatibility characteristics	Material			
					Cylinder		Valve (body and components)	
					A	N	A	N
59	(UN 1050)	HYDROGEN CHLORIDE	HCl	This compound is highly hygroscopic and corrosive in wet conditions with most of the materials except some high corrosion resistant nickel alloys (e.g. Hastelloy©[1]). QTS are limited to a maximum ultimate tensile strength of 950 MPa. This limitation also applies to mixtures containing this gas and stored at a total pressure at 15 °C greater than half the normal service pressure of the cylinder. However, experience shows that a cylinder can be safely used without any specific strength limitation requirements, providing the maximum working pressure at 15 °C in the cylinder is less than one-fifth of the test pressure (TP/5), in order to maintain a low stress level in the cylinder material. SS shall not be used for valve diaphragm and springs except if the failure of such components does not result in an unsafe situation. Mixtures of dry gas not exceeding 0,1 % of this gas may be filled into AA cylinders.	**NS** **QTS** SS Ni	AA	CS SS **Ni**	AA B
60	(UN 1050)	HYDROGEN CYANIDE	HCN	This compound is highly hygroscopic. Risk of corrosion in wet conditions, depending on type of alloy.	**NS** QTS AA SS		**B** CS SS AA	

[a] Brass is only acceptable as a valve body but not as a general valve component material.

[b] For mixtures containing up to 1 000 ppm of dry NO, brass valves can be used.

Table 1 *(continued)*

No.	Gas number UN number	Name	Formula	Key compatibility characteristics	Material			
					Cylinder		Valve (body and components)	
					A	N	A	N
61	(UN 1052)	HYDROGEN FLUORIDE	HF	This compound is highly hygroscopic and corrosive in wet conditions with most of the materials except some high corrosion resistant nickel alloys (e.g. Hastelloy©[1]). QTS are limited to a maximum ultimate tensile strength of 950 MPa. This limitation also applies to mixtures containing the gas stored at a total pressure at 15 °C greater than half the normal service pressure of the cylinder. However, experience shows that a cylinder can be safely used without any specific strength limitation requirements, providing the maximum pressure at 15 °C in the cylinder is less than one-fifth of the test pressure (TP/5), in order to maintain a low stress level in the cylinder material. SS shall not be used for valve diaphragms or springs except if the failure of such components does not result in an unsafe situation. Mixtures of dry gas not exceeding 0,1 % of this gas may be filled into AA cylinders.	**NS** **QTS** SS Ni	AA	CS **SS** **Ni**	AA

[a] Brass is only acceptable as a valve body but not as a general valve component material.

[b] For mixtures containing up to 1 000 ppm of dry NO, brass valves can be used.

Table 1 *(continued)*

No.	Gas number UN number	Name	Formula	Key compatibility characteristics	Material			
					Cylinder		Valve (body and components)	
					A	N	A	N
62	(UN 2197)	HYDROGEN IODIDE	HI	This compound is highly hygroscopic and corrosive in wet conditions with most of the materials, except some high corrosion resistant nickel alloys (e.g. Hastelloy©[1]). QTS are limited to a maximum ultimate tensile strength of 950 MPa. This limitation also applies to mixtures containing this gas and stored at a total pressure at 15 °C greater than half the normal service pressure of the cylinder. However, experience shows that a cylinder can be safely used without any specific strength limitation requirements, providing the maximum pressure at 15 °C in the cylinder is less than one-fifth of the test pressure (TP/5), in order to maintain a low stress level in the cylinder material. SS shall not be used for valve diaphragm and springs except if the failure of such components does not result in an unsafe situation. Mixtures of dry gas not exceeding 0,1 % of this gas may be filled into AA cylinders.	**NS** **QTS** SS Ni	AA	CS **SS** **Ni**	AA B

[a] Brass is only acceptable as a valve body but not as a general valve component material.

[b] For mixtures containing up to 1 000 ppm of dry NO, brass valves can be used.

Table 1 *(continued)*

No.	Gas number UN number	Name	Formula	Key compatibility characteristics	Material			
					Cylinder		Valve (body and components)	
					A	N	A	N
63	(UN 1053)	HYDROGEN SULPHIDE	H_2S	— In the presence of free water, pitting corrosion can occur. Pitting corrosion can be minimized by using SS alloys such as 316. — In wet conditions, risk of stress corrosion cracking for QTS. Risk of hydrogen embrittlement with NS, QTS. — SS shall not be used for springs or diaphragms except if the failure of such components does not result in an unsafe situation because of possibility of hydrogen embrittlement. — For mixtures with higher partial pressure than the one defined in 6.2 and stored at a total pressure greater than 50 % of the normal service pressure of the cylinder, NS, and QTS at a limited strength shall be used (see 6.2). — Refined nickel is not acceptable for bursting disks and components.	**NS** **QTS** AA SS		CS **SS** AA	B
64	(UN 1969)	ISOBUTANE	$CH(CH_3)_3$	No reaction with any common materials; however, in wet conditions risk of corrosion from impurities shall be considered.	**NS** QTS AA SS		**B** CS SS AA	
65	(UN 1055)	ISOBUTYLENE	$CH_2{:}C(CH_3)_2$	No reaction with any common materials; however, in wet conditions risk of corrosion from impurities shall be considered.	**NS** QTS SS AA		**B** CS SS AA	

[a] Brass is only acceptable as a valve body but not as a general valve component material.

[b] For mixtures containing up to 1 000 ppm of dry NO, brass valves can be used.

Table 1 *(continued)*

No.	Gas number UN number	Name	Formula	Key compatibility characteristics	Material			
					Cylinder		Valve (body and components)	
					A	N	A	N
66	(UN 1056)	KRYPTON	Kr	No reaction with any common materials in dry or wet conditions.	NS **QTS** AA SS		**B** CS SS AA	
67	(UN 1971)	METHANE	CH_4	No reaction with any common materials; however, in wet conditions risk of corrosion from impurities such as traces of CO, H_2S, CO_2 shall be considered (see CO, H_2S, CO_2 compatibility). NOTE For natural gas see also specific compatibility requirements in ISO 11439.	**NS** **QTS** **AA** SS		**B** CS SS AA	
68	(See 6.3.1)	PROPYNE	C_3H_4	May contain traces of acetylene. The ability to form explosive acetylides has to be considered. If the C_2H_2 content exceeds 1 % see C_2H_2.	**NS** QTS AA SS		**B** **CS** SS AA	
69	(UN 1062)	METHYL BROMIDE	CH_3Br (R40B1)	In the presence of free water pitting corrosion can occur. Pitting corrosion can be minimized by using SS alloys such as 316. Mixtures of dry gas not exceeding 0,1 % of this gas may be filled into AA cylinders.	**NS** **QTS** SS	AA	B CS **SS** Ni	AA

[a] Brass is only acceptable as a valve body but not as a general valve component material.

[b] For mixtures containing up to 1 000 ppm of dry NO, brass valves can be used.

Table 1 *(continued)*

No.	Gas number UN number	Name	Formula	Key compatibility characteristics	Material			
					Cylinder		Valve (body and components)	
					A	N	A	N
70	(UN 1064)	METHYL MERCAPTAN	CH_3SH	— In the presence of free water, pitting corrosion can occur. Pitting corrosion can be minimized by using SS alloys such as 316. — In wet conditions risk of stress corrosion cracking for QTS. — Risk of hydrogen embrittlement with NS, QTS and some SS. — SS may be used for valve diaphragms and springs when there is operating experience that shows the design is suitable and safe. Alternatively, use is also authorized if failure of the SS springs or SS diaphragms does not result in an unsafe condition. NOTE Some SS alloys are sensitive to hydrogen embrittlement. — For mixtures with higher partial pressure than the one defined in 6.2, stored at a total pressure greater than 50 % the normal service pressure of the cylinder, NS and QTS are limited to a maximum strength of 950 MPa. — Refined nickel is not acceptable for bursting disks and components.	**NS** **QTS** AA SS		**B** CS SS AA	

[a] Brass is only acceptable as a valve body but not as a general valve component material.

[b] For mixtures containing up to 1 000 ppm of dry NO, brass valves can be used.

Table 1 *(continued)*

No.	Gas number UN number	Name	Formula	Key compatibility characteristics	Material			
					Cylinder		Valve (body and components)	
					A	N	A	N
71	(See 6.3.1)	METHYL SILANE	CH_3SiH_3	— QTS are limited to a maximum ultimate tensile strength of 950 MPa. — SS shall not be used for springs or diaphragms, except if the failure of components does not result in an unsafe situation. — Risk of corrosion by impurities in wet conditions shall be considered, e.g. contamination by sulphuric acid from some manufacturing processes.	**NS** **QTS** AA SS		**B** CS **SS** AA	
72	(UN 1061)	METHYLAMINE	CH_3NH_2	Risk of stress corrosion cracking with brass (and other copper alloys) valves due to atmospheric moisture. This applies to all gases and mixtures containing even traces of CH_3NH_2.	**NS** QTS AA SS Ni		**CS** **SS** AA Ni	B
73	(UN 1065)	NEON	Ne	No reaction with any common materials in dry or wet conditions.	NS **QTS** AA SS		**B** CS SS AA	
74	(UN 1660)	NITRIC OXIDE	NO	In the presence of free water, pitting corrosion can occur. Pitting corrosion can be minimized by using SS alloys such as 316. Risk of stress corrosion cracking with brass (and other copper alloys) valves due to atmospheric moisture. This applies to all mixtures containing even traces of NO.	**NS** **QTS** **AA** SS		CS **SS**	B[b] AA

[a] Brass is only acceptable as a valve body but not as a general valve component material.

[b] For mixtures containing up to 1 000 ppm of dry NO, brass valves can be used.

Table 1 *(continued)*

No.	Gas number UN number	Name	Formula	Key compatibility characteristics	Material			
					Cylinder		Valve (body and components)	
					A	N	A	N
75	(UN 1066)	NITROGEN	N_2	No reaction with any common materials in dry or wet conditions.	NS **QTS** AA SS		**B** CS SS AA	
76	(UN 1067)	NITROGEN DIOXIDE	NO_2	In the presence of free water, pitting corrosion can occur. Pitting corrosion can be minimized by using SS alloys such as 316. Risk of stress corrosion cracking with brass (and other copper alloys) valves due to atmospheric moisture. This applies to all mixtures containing even traces of NO_2.	NS **QTS** AA SS		CS **SS** AA AA	B AA
77	(UN 1070)	NITROUS OXIDE	N_2O	Risk of stress corrosion cracking for brass and other copper alloy highly stressed components (for any concentration). The potential risk of violent reaction (ignition), especially for valves, shall be considered at the design stage in accordance with ISO 11114-2, ISO 11114-3 and ISO 10297.	**NS** **QTS** **AA** SS		**B** **CS** SS AA	
78	(UN 2451)	NITROGEN TRIFLUORIDE	NF_3	No reaction with any common materials when dry. Becomes a strong oxidizer when decomposed.	**NS** QTS SS AA		B CS SS AA	
79	(UN 2422)	OCTOFLUOROBUT-2-ENE	C_4F_8	No reaction with any common materials when dry, but in the presence of free water corrosion occurs.	**NS** QTS AA SS		**B** CS SS AA	

[a] Brass is only acceptable as a valve body but not as a general valve component material.

[b] For mixtures containing up to 1 000 ppm of dry NO, brass valves can be used.

Table 1 *(continued)*

No.	Gas number UN number	Name	Formula	Key compatibility characteristics	Material			
					Cylinder		Valve (body and components)	
					A	N	A	N
80	(UN 1976)	OCTAFLUOROCYCLOBUTANE	C_4F_8 (RC318)	No reaction with any common materials when dry, but in the presence of free water corrosion occurs.	NS **QTS** AA SS		**B** CS SS AA	
81	(UN 2424)	OCTAFLUOROPROPANE	C_3F_8 (R218)	No reaction with any common materials when dry, but in the presence of free water corrosion occurs.	NS **QTS** AA SS		**B** CS SS AA	
82	(UN 1072)	OXYGEN	O_2	In the presence of free water, NS, QTS and CS are corroded. Water ingress in cylinders should be avoided, e.g. by use of cylinder valves with RPV (residual pressure valve). The potential risk of violent reaction (ignition), especially for valves, shall be considered at the design stage in accordance with ISO 11114-2, ISO 11114-3 and ISO 10297. Cylinder valves shall be subject to testing to establish their suitability for oxygen service and their resistance to ignition (see ISO 11114-2, ISO 11114-3 and ISO 10297). Copper alloys shall contain no more than 2,5% aluminium content. Design assessment by a competent person is recommended before using SS for springs and other internal gas wetted components, unless ignition does not create safety issues.	**NS** **QTS** **AA** SS		**B** CS SS	AA

[a] Brass is only acceptable as a valve body but not as a general valve component material.

[b] For mixtures containing up to 1 000 ppm of dry NO, brass valves can be used.

Table 1 *(continued)*

No.	Gas number UN number	Name	Formula	Key compatibility characteristics	Material			
					Cylinder		Valve (body and components)	
					A	N	A	N
83	(UN 1076)	PHOSGENE	$COCl_2$	In wet conditions, phosgene is corrosive with most materials, particularly aluminium alloys (hydrolyses to HCl). Mixtures of dry gas containing not more than 0,1 % of this gas may be filled into AA cylinders.	**NS** QTS SS **Ni**	AA	**B** **CS** SS Ni	AA
84	(UN 2199)	PHOSPHINE	PH_3	Because of risk of hydrogen embrittlement: — QTS are limited to a maximum ultimate tensile strength of 950 MPa; — SS may be used for valve diaphragms and springs when there is operating experience that shows the design is suitable and safe. Alternatively, use is also authorized if failure of the SS springs or SS diaphragms does not result in an unsafe condition. NOTE Some SS alloys are sensitive to hydrogen embrittlement. See special conditions for mixtures given in 6.2.	**NS** **QTS** AA SS		**B** CS **SS** AA	
85	(UN 1978)	PROPANE	C_3H_8	No reaction with any common materials; however, in wet conditions the risk of corrosion from impurities shall be considered.	**NS** QTS AA SS		**B** CS SS AA	
86	(UN 2200)	PROPADIENE	C_3H_4	No reaction with any common materials; however, in wet conditions the risk of corrosion from impurities shall be considered.	**NS** QTS AA SS		**B** CS SS AA	

[a] Brass is only acceptable as a valve body but not as a general valve component material.

[b] For mixtures containing up to 1 000 ppm of dry NO, brass valves can be used.

Table 1 *(continued)*

No.	Gas number UN number	Name	Formula	Key compatibility characteristics	Material			
					Cylinder		Valve (body and components)	
					A	N	A	N
87	(UN 1077)	PROPYLENE	C_3H_6	No reaction with any common materials; however, in wet conditions the risk of corrosion from impurities shall be considered.	**NS** QTS AA SS		**B** CS SS AA	Cu
88	(UN 1280)	PROPYLENE OXIDE	C_3H_6O	Propylene oxide polymerizes. The rate of polymerization increases in the presence of moisture, rust and other contaminants. Use a clean, dry cylinder. Copper is not acceptable.	**NS** **QTS** AA SS	Cu	**B** CS SS AA	Cu
89	(UN 2203)	SILANE	SiH_4	— The filling ratio shall be limited to 320 g/L for steels with tensile strengths above 950 MPa. — SS may be used for valve diaphragms and springs when there is operating experience that shows the design is suitable and safe. Alternatively, use is also authorized if failure of the SS springs or SS diaphragms does not result in an unsafe condition. NOTE Some SS alloys are sensitive to hydrogen embrittlement. See special conditions for mixtures given in 6.2. Risk of corrosion by impurities in wet conditions shall be considered, e.g. contamination by sulphuric acid from some manufacturing processes.	**NS** **QTS** SS AA		**B** CS **SS** AA	
90	(UN 1818)	SILICON TETRACHLORIDE	$SiCl_4$	Hydrolyses to hydrogen chloride in contact with moisture. In wet conditions, see specific risk of hydrogen chloride compatibility, i.e. severe corrosion of most materials. Mixtures of dry gas not exceeding 0,1 % of this gas may be filled into AA cylinders.	**NS** **QTS** SS Ni	AA	CS **B** SS Ni	AA

[a] Brass is only acceptable as a valve body but not as a general valve component material.

[b] For mixtures containing up to 1 000 ppm of dry NO, brass valves can be used.

Table 1 *(continued)*

No.	Gas number UN number	Name	Formula	Key compatibility characteristics	Material			
					Cylinder		Valve (body and components)	
					A	N	A	N
91	(UN 1859)	SILICON TETRAFLUORIDE	SiF_4	Hydrolyses to hydrogen fluoride in contact with moisture. In wet conditions, see specific risk of hydrogen fluoride compatibility, i.e. severe corrosion of most materials. Mixtures of dry gas not exceeding 0,1 % of this gas may be filled into AA cylinders.	**NS** **QTS** SS **Ni**	AA	CS **B** **SS** Ni	AA
92	(UN 1079)	SULPHUR DIOXIDE	SO_2	Highly hygroscopic. Sulphur dioxide hydrolyses in presence of free water to produce sulphurous acid, which is highly corrosive to steel. In the presence of free water, pitting corrosion can occur. Pitting corrosion can be minimized by using SS alloys such as 316. B might suffer stress corrosion cracking, in long-term wet conditions.	**NS** **QTS** **AA** SS		B CS **SS** AA Ni	
93	(UN 1080)	SULPHUR HEXAFLUORIDE	SF_6	No reaction with any common materials.	NS **QTS** **AA** SS		**B** CS SS AA	
94	(UN 2418)	SULPHUR TETRAFLUORIDE	SF_4	In wet conditions, sulphur tetrafluoride is highly corrosive. SS alloys such as 316 and Nickel alloys may be used. Mixtures of dry gas not exceeding 0,1 % of this gas may be filled into AA cylinders.	**NS** **QTS** **SS**	AA	B CS SS Ni	AA
95	(UN 1081)	TETRAFLUOROETHYLENE	C_2F_4 (R1114)	No reaction with any common materials when dry, but in the presence of free water corrosion can occur.	NS **QTS** AA SS		**B** CS SS AA	

[a] Brass is only acceptable as a valve body but not as a general valve component material.

[b] For mixtures containing up to 1 000 ppm of dry NO, brass valves can be used.

Table 1 *(continued)*

No.	Gas number UN number	Name	Formula	Key compatibility characteristics	Material			
					Cylinder		Valve (body and components)	
					A	N	A	N
96	(UN 1295)	TRICHLOROSILANE	$SiHCl_3$	Hydrolyses to hydrogen chloride in contact with moisture. In wet conditions, see specific risk of hydrogen chloride compatibility, i.e. severe corrosion of most of the materials. Mixtures of dry gas not exceeding 0,1 % of this gas may be filled into AA cylinders.	**NS** **QTS** SS Ni	AA	B CS **SS** Ni	AA
97	(See 6.3.1)	TRICHLOROTRIFLUOROETHANE	$C_2Cl_3F_3$ (R113)	No reaction with any common materials when dry, but in the presence of free water corrosion occurs.	NS **QTS** AA SS		**B** CS SS AA Ni	
98	(UN 2035)	1,1,1-TRIFLUOROETHANE	CH_3CF_3 (R143a)	No reaction with any common materials when dry, but in the presence of free water corrosion occurs.	**NS** **QTS** AA SS		**B** CS SS AA	
99	(UN 1083)	TRIMETHYLAMINE	$(CH_3)_3N$	Risk of stress corrosion cracking with brass (and other copper alloys) valves due to atmospheric moisture. This applies to all gases and mixtures containing even traces of NH_3.	**NS** QTS AA SS Ni		**CS** **SS** AA Ni	B

[a] Brass is only acceptable as a valve body but not as a general valve component material.

[b] For mixtures containing up to 1 000 ppm of dry NO, brass valves can be used.

Table 1 *(continued)*

No.	Gas number UN number	Name	Formula	Key compatibility characteristics	Material			
					Cylinder		Valve (body and components)	
					A	N	A	N
100	(UN 2196)	TUNGSTEN HEXAFLUORIDE	WF_6	Hydrolyses to hydrogen fluoride in contact with moisture. In wet conditions, see specific risk of hydrogen fluoride compatibility, i.e. severe corrosion of most materials and risk of hydrogen embrittlement. Due to their highly corrosive-resistant nature, nickel-based alloys and nickel-plated valves are recommended. Mixtures containing less than 0,1 % of this gas may be filled into AA cylinders.	**NS** **QTS** SS Ni	AA	CS **SS** Ni	AA
101	(UN 1085)	VINYL BROMIDE	C_2H_3Br (R1140B1)	Risk of corrosion in wet conditions. Some C_2H_2 contamination could be present. Mixtures containing less than 0,1 % of this gas may be filled into AA cylinders.	**NS** **QTS** SS **Ni**	AA	B CS **SS** Ni	AA
102	(UN 1086)	VINYL CHLORIDE	C_2H_3Cl (R1140)	Risk of corrosion in wet conditions. Some C_2H_2 contamination could be present. Mixtures containing less than 0,1 % of this gas may be filled into AA cylinders.	**NS** **QTS** SS Ni	AA	B CS **SS** Ni	AA
103	(UN 1860)	VINYL FLUORIDE	C_2H_3F (R1141)	Risk of corrosion in wet conditions. Some C_2H_2 contamination could be present. Mixtures containing less than 0,1 % of this gas may be filled into AA cylinders.	**NS** **QTS** SS Ni	AA	B CS SS Ni	AA
104	(UN 2036)	XENON	Xe	No reaction with any common materials in dry or wet conditions.	NS **QTS** SS AA		**B** CS SS AA	

[a] Brass is only acceptable as a valve body but not as a general valve component material.

[b] For mixtures containing up to 1 000 ppm of dry NO, brass valves can be used.

Table 1 *(continued)*

No.	Gas number UN number	Name	Formula	Key compatibility characteristics	Material			
					Cylinder		Valve (body and components)	
					A	N	A	N

[1] Incoloy© and Hastelloy© are examples of suitable products available commercially. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of these products.

[a] Brass is only acceptable as a valve body but not as a general valve component material.

[b] For mixtures containing up to 1 000 ppm of dry NO, brass valves can be used.

Annex A
(informative)

Gas/materials NQSAB compatibility code

A.1 General

A five-digit code allows a rating of the compatibility of each gas with five different classes of materials for use with gas cylinders and cylinder valves. This is termed the NQSAB code, where "N" represents normalized steels and carbon steels, "Q" quenched and tempered steels, "S" stainless steels, "A" aluminium alloys and "B" brass and other copper alloys, and nickel alloys. The degree of compatibility is identified by replacing the letter with the appropriate digit as described in A.2.

A.3 presents the NQSAB code itself, and in A.4 the gases covered in this part of ISO 11114 are divided into 11 groups, depending on their compatibility with cylinder and valve materials.

A.2 Material classes and compatibility identification

A.2.1 Normalized steels and carbon steels (N)

0 Not acceptable.

1 Acceptable but check Table 1, key compatibility characteristics.

9 Acceptable but check Table 1, key compatibility characteristics, to avoid hydrogen embrittlement.

A.2.2 Quenched and tempered steels (Q)

0 Not acceptable.

1 Acceptable but check Table 1, key compatibility characteristics.

9 Acceptable but check Table 1, key compatibility characteristics, to avoid hydrogen embrittlement.

A.2.3 Stainless steels (S)

0 Not acceptable.

1 Acceptable for gas cylinder but check Table 1, key compatibility characteristics.

2 Pitting corrosion can be minimized by using stainless steel alloys such as 316.

9 Hydrogen embrittlement can be minimized by using stainless steel alloys such as 316.

A.2.4 Aluminium alloys (A)

0 Not acceptable but some mixtures of dry gases may be filled into AA; check Table 1, key compatibility characteristics.

1 Acceptable but check Table 1, key compatibility characteristics.

A.2.5 Brass and other copper alloys (B)

0 Not acceptable.

1 Acceptable to be used but check Table 1, key compatibility characteristics.

3 Use brass or other copper alloys containing less than 65 % Cu.

A.3 NQSAB code

The NQSAB code for each gas is given in Table A.1. For gases where the compatibility rating 2, 3 or 9 are specified, refer also to Table 1.

Table A.1 — List of gases with corresponding NQSAB compatibility code

Name and gas number	Formula	N	Q	S	A	B
1 ACETYLENE	C_2H_2	1	1	1	1	3
2 AMMONIA	NH_3	1	1	1	1	0
3 ARGON	Ar	1	1	1	1	1
4 ARSINE	AsH_3	9	9	9	1	1
5 BORON TRICHLORIDE	BCl_3	1	1	2	0	0
6 BORON TRIFLUORIDE	BF_3	1	1	2	0	0
7 BROMOCHLORODIFLUOROMETHANE	$CBrClF_2$ (R12B1)	1	1	1	1	1
8 BROMOTRIFLUOROMETHANE	$CBrF_3$ (R13B1)	1	1	1	1	1
9 BROMOTRIFLUOROETHYLENE	C_2BrF_3	1	1	1	1	1
10 BUTADIENE-1,3	$H_2C{:}CHCH{:}CH_2$	1	1	1	1	1
11 BUTADIENE-1,2	$H_2C{:}C{:}CHCH_3$	1	1	1	1	1
12 BUTANE	C_4H_{10}	1	1	1	1	1
13 BUTENE-1	$CH_3CH_2CH{:}CH_2$	1	1	1	1	1
14 BUTENE-2 (CIS)	$CH_3CH{:}CHCH_3$	1	1	1	1	1
15 BUTENE-2 (TRANS)	$CH_3CH{:}CHCH_3$	1	1	1	1	1
16 CARBON DIOXIDE	CO_2	1	1	1	1	1
17 CARBON MONOXIDE	CO	1	1	1	1	1