
**Transportable gas cylinders —
Compatibility of cylinder and valve
materials with gas contents —**

**Part 4:
Test methods for selecting steels
resistant to hydrogen embrittlement**

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

*Partie 4: Méthodes d'essai pour le choix des aciers résistants à la
fragilisation par l'hydrogène*

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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 on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

The committee responsible for this document is ISO/TC 58, *Gas cylinders*.

This second edition cancels and replaces the first edition (ISO 11114-4:2005), which has been technically revised with the following changes:

- improvement of the procedure corresponding to Method C and adjustment of acceptance criteria;
- light modifications on procedures corresponding to Method A and Method B.

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

Introduction

It is widely recognized that compressed hydrogen and some hydrogen bearing gases can have an embrittling effect on steels. This embrittling effect has resulted in the failure of hydrogen gas cylinders (including some bursts) that has led gas cylinder users and manufacturers to adopt specific measures.

The adoption of these measures has eliminated all known failures of hydrogen cylinders from this embrittlement phenomenon as far has been reported.

The basic recommendation is to limit the tensile strength of the steels (see ISO 11114-1) and eliminate manufacturing defects.

This tensile strength limit of 950 MPa was developed for quenched and tempered gas cylinders of 34 Cr Mo 4 type steels using steelmaking practices, chemistry and manufacturing techniques typical of those used during the early 1980's and successfully used for filling pressures up to 300 bar. This practice has been in widescale use up to the current time. Other higher pressures, although at lower tensile strength limits, have also been used.

In recent years, improvements in steelmaking, e.g. by reducing the sulphur and phosphorus contents, have indicated the possibility of increasing the tensile strength limit of 950 MPa for embrittling gas service. Experimental work has shown that the relevant parameters affecting hydrogen embrittlement are the following:

- a) microstructure resulting from the combination of the chemistry and the heat treatment;
- b) mechanical properties of the material;
- c) applied stress;
- d) internal surface imperfections resulting in local stress concentrations;
- e) characteristics of the gas contained (composition, quality, pressure, etc.).

When developing this document, only the material aspects, a) and b) and the characteristics of the gas e) above, were considered. Other essential features, c) and d), are covered by the relevant parts of ISO 9809.

Some low alloy steels other than 34 Cr Mo 4 may require tensile strength to be lower than 950 MPa, or may be permitted to be higher than 950 MPa, to be suitable for the manufacture of gas cylinders for embrittling gas service.

This document specifies test methods to identify steels which, when combined with the cylinder manufacturing requirements specified in ISO 9809 (all parts), will result in cylinders suitable for use in embrittling gas service.

These tests have been developed following an extensive world-wide programme which incorporated laboratory and full scale tests. See also AFNOR FD E29-753.

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

Part 4: Test methods for selecting steels resistant to hydrogen embrittlement

1 Scope

This document specifies test methods and the evaluation of results from these tests in order to qualify steels suitable for use in the manufacture of gas cylinders (up to 3 000 l) for hydrogen and hydrogen bearing embrittling gases.

This document only applies to seamless steel gas cylinders.

The requirements of this document are not applicable if at least one of the following conditions for the intended gas service is fulfilled:

- the working pressure of the filled embrittling gas is less than 20 % of the test pressure of the cylinder;
- the partial pressure of the filled embrittling gas of a gas mixture is less than 5 MPa (50 bar) in the case of hydrogen and other embrittling gases, with the exception of hydrogen sulphide and methyl mercaptan; in such cases, the partial pressure shall not exceed 0,25 MPa (2,5 bar).

NOTE In such cases, it is possible to design the cylinder as for ordinary (non-embrittling) gases.

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 7539-1, *Corrosion of metals and alloys — Stress corrosion testing — Part 1: General guidance on testing procedures*

ISO 7539-6:2011, *Corrosion of metals and alloys — Stress corrosion testing — Part 6: Preparation and use of precracked specimens for tests under constant load or constant displacement*

ISO 9809-1, *Gas cylinders — Refillable seamless steel gas cylinders — Design, construction and testing — Part 1: Quenched and tempered steel cylinders with tensile strength less than 1 100 MPa*

ISO 9809-2, *Gas cylinders — Refillable seamless steel gas cylinders — Design, construction and testing — Part 2: Quenched and tempered steel cylinders with tensile strength greater than or equal to 1 100 MPa*

ISO 11114-1:2012, *Gas cylinders — Compatibility of cylinder and valve materials with gas contents — Part 1: Metallic materials*

ISO 11120, *Gas cylinders — Refillable seamless steel tubes of water capacity between 150 l and 3000 l — Design, construction and testing*