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Standard**

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**Ships and marine technology — Test
procedures for liquid hydrogen
storage tank of hydrogen ships**

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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 document 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).

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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 8, *Ships and marine technology*, Subcommittee SC 3, *Piping and machinery*.

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

Hydrogen offers a reliable way to decarbonise a variety of sectors including the maritime industry, where it has been historically difficult to meaningfully reduce CO₂ emissions despite the commitments by governments and the implementation of regulatory measures.

There are technologies available that enable hydrogen to be produced, stored, transported and used as energy in different ways. Various materials can be produced by hydrogen, including renewable energy, natural gas, coal and oil. Hydrogen can be transported as a gas by pipelines or in liquid form by ship, much like liquid natural gas (LNG), and transformed into electric energy to provide homes or industry with power and also into fuels for cars, trucks, ships and planes.

However, the safe and wide use of hydrogen in marine industry faces several challenges, in particular the absence of applicable international standards on the safety testing of hydrogen systems. All system components should be designed and tested for the safety and reliability in handling liquid hydrogen and thereby the facilitation of decarbonisation with the transition into hydrogen-based clean energy.

In this regard, this document sets up a general test requirement for the liquid hydrogen cargo tank of hydrogen carrier ships. It is expected that useful information can be provided to the marine industry stakeholders including ship owners, classification societies and shipyards. Finally, this document aims to contribute to the growth of relevant industries and benefit all related stakeholders.

Ships and marine technology — Test procedures for liquid hydrogen storage tank of hydrogen ships

1 Scope

This document specifies general inspection and test requirements for liquid hydrogen cargo tanks on board hydrogen carrier ships. In the cases of liquefied hydrogen containment systems, the testing activity depends strictly on the type of storage containment technology identified by the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code).^[1] This document is applicable to Type C independent metallic double wall type tanks with vacuum insulation having a capacity of not more than 1 000 cubic metres (m³). It is also applicable to liquid hydrogen cargo tanks which are designed to transport pure para-hydrogen (not less than 95 % content).

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 11114-4, *Transportable gas cylinders — Compatibility of cylinder and valve materials with gas contents — Part 4: Test methods for selecting steels resistant to hydrogen embrittlement*

ISO 17636-1, *Non-destructive testing of welds — Radiographic testing — Part 1: X- and gamma-ray techniques with film*

ISO 17636-2, *Non-destructive testing of welds — Radiographic testing — Part 2: X- and gamma-ray techniques with digital detectors*

ISO 3452-1, *Non-destructive testing — Penetrant testing — Part 1: General principles*

ISO 9934-1, *Non-destructive testing — Magnetic particle testing — Part 1: General principles*

ISO 23208, *Cryogenic vessels — Cleanliness for cryogenic service*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

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

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

— IEC Electropedia: available at <https://www.electropedia.org/>

3.1 design pressure

pressure used to determine minimum scantlings of the *liquefied hydrogen (LH₂)* (3.3) storage tank

3.2 maximum allowable working pressure MAWP

maximum pressure of a storage tank determined by the tank design code

Note 1 to entry: MAWP should not be less than the *design pressure* (3.1).

3.3 liquefied hydrogen LH₂

hydrogen that has been cooled and condensed into liquid form

Note 1 to entry: LH₂ is a cryogenic liquid having a temperature typically around –253 ° Celsius under normal atmospheric pressure.

3.4 para-hydrogen

one of the two isomers of the hydrogen molecule where the nuclear spins of the two atoms are opposed

3.5 independent tank

self-supporting tank that does not form part of the ship's hull and is not essential to the hull strength

Note 1 to entry: The design basis for type C independent tanks is based on pressure vessel criteria modified to include fracture mechanics and crack propagation criteria.

3.6 cold spot

part of the hull or thermal insulation surface where a localized temperature decrease occurs with respect to the allowable minimum temperature of the hull or its adjacent hull structure, or design capabilities of cargo pressure and temperature control systems

4 Abbreviated terms

For the purpose of this document, the following abbreviated terms apply

IMO	International Maritime Organization
MSC	Maritime Safety Committee
IGC Code	International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk
IACS	International Association of Classification Societies
ASME	American Society of Mechanical Engineers

5 Inspection and tests

5.1 General

Tests shall be conducted on new design Type C independent tanks for liquid hydrogen storage on hydrogen carrier ships. All tanks subjected to type tests shall be made unusable after the tests are completed.

The LH₂ storage tank provider shall preserve the type test results for the intended life of the storage tank design. The test result shall also document the tank specification.

[Annex B](#) gives an example of general inspection and test procedures. The liquid hydrogen storage tank may be subjected to inspection and tests specified in [Annex B](#), under mutual agreement between owner and the LH₂ storage tank provider.

[Annex E](#) provides an example figure of the design and installation arrangements of a vacuum-insulated LH₂ cargo tank, with various piping and instrumentation normally attached to the tank.

[Annex A](#) provides information regarding other potential hazards and safety considerations associated with the storage and containment of liquefied hydrogen.

5.2 Design appraisal

Liquid hydrogen storage tank drawings and material specifications shall be submitted to the owner or classification society for written approval before test implementation. The owner or classification society shall approve of the drawings.

An example of the drawings which can be submitted are listed in [Annex C](#).

5.3 Material inspection

Material property testing of liquid hydrogen storage tanks, which are required for the acceptance of use by the classification society or ship owner where the minimum design temperature is less than $-196\text{ }^{\circ}\text{C}$, shall be carried out with the appropriate medium within the range between the maximum design temperature in service (normally taken as $45\text{ }^{\circ}\text{C}$) and the temperature lower than the minimum design temperature by at least $5\text{ }^{\circ}\text{C}$.

The hydrogen embrittlement test shall be carried out and materials shall be selected to ensure the safety of liquid hydrogen cargo tanks. Reference should also be made to the "Guide to Safety of Hydrogen and Hydrogen systems" published by the American Institute of Aeronautics and Astronautics (AIAA),^[3] as referenced in IMO Resolution MSC. 420(97).^[22]

The hydrogen embrittlement test shall be carried out to provide evidence that the metallic double wall type hydrogen storage tank is not susceptible to hydrogen embrittlement. In hydrogen storage tanks that are subject to frequent evaporated gaseous form, conditions can lead to local fatigue, and the initiation and propagation of fatigue cracks induced by ship motion in the liquid hydrogen cargo tanks. The hydrogen compatibility shall be tested in accordance with ISO 11114-4.

Test results should show that the selected materials for liquid hydrogen storage tanks are suitable for their specific operating conditions and environment, taking into account factors such as design temperature, pressure, working stress and other environmental conditions.

5.4 Welding inspection

All welded joints of the shells and domes to shell of liquid hydrogen storage tanks shall be of the butt weld full penetration type to prevent leakage of hydrogen. For nozzle or other penetration connections, either fillet welds or the full penetration type may be used depending on the results of the tests carried out, after getting approval of the welding procedure. Otherwise, if the nozzle or other penetration is made of forgings with an integral forged ring to match the contour of the dome or shell, the joint shall use full penetration butt welds.

All welded points of the liquid hydrogen storage tank between the inner tank and outer tank shall be subjected to non-destructive test inspection. All butt welds of liquid hydrogen storage tanks shall be subjected to radiographic testing in accordance with ISO 17636-1 and ISO 17636-2. Where welding points of the liquid hydrogen storage tank cannot be radiographed, these welds shall be subjected to penetrant testing in accordance with ISO 3452-1, magnetic particle testing in accordance with ISO 9934-1, and approved ultrasonic testing.

5.5 Hydrostatic test

A hydrostatic test shall be carried out at a pressure measured at the top of tank.

The test pressure shall be at least 1,5 times the design pressure. At no point during the pressure test shall the calculated primary membrane stress exceed 90 % of the yield stress of the material. To ensure that this condition is satisfied where calculations indicate that this stress will exceed 0,75 times the yield strength, the type test shall be monitored using strain gauges or other suitable equipment in pressure vessels, other than simple cylindrical and spherical pressure vessels.

The temperature of the water used for the test shall be at least $30\text{ }^{\circ}\text{C}$ above the nil-ductility transition temperature of the material, as fabricated. The pressure shall be held for 2 h per 25 mm of thickness, but in no case less than 2 h.