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INTERNATIONAL ORGANIZATION FOR STANDARDIZATION • МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ • ORGANISATION INTERNATIONALE DE NORMALISATION

Liquid hydrogen — Land vehicle fuel tanks —

Part 1:
Design, fabrication, inspection and testing

Hydrogène liquide — Réservoirs de carburant pour véhicules terrestres —

Partie 1: Conception, fabrication, inspection et essais

ICS 43.060.40

Member bodies are reminded to consult relevant national interests in each of the technical fields concerned [*Hydrogen technologies* (ISO/TC 197) and *Road vehicles* (ISO/TC 22)] before returning their ballot to the Central Secretariat.

To expedite distribution, this document is circulated as received from the committee secretariat. ISO Central Secretariat work of editing and text composition will be undertaken at publication stage.

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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 3.

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 part of ISO 13985 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 13985-1 was prepared by Technical Committee ISO/TC 197, *Hydrogen technologies*.

ISO 13985 consists of the following parts, under the general title *Liquid hydrogen — Land vehicle fuel tanks*:

— *Part 1: Design, fabrication, inspection and testing*

— *Part 2: Installation and maintenance*

Please note that ISO 13985 was separated in two parts based on the comments received during the circulation of the first enquiry draft. This second DIS vote therefore follows the first DIS vote on the original one part document identified as ISO/DIS 13985.

Introduction

The fuel tanks described in this International Standard is intended to be used in conjunction with the fuelling system interface described in ISO 13984: 1999.

Liquid hydrogen — Land vehicle fuel tanks — Part 1: Design, fabrication, inspection and testing

1 Scope

This part of ISO 13985~~International Standard~~ specifies the requirements for refillable tanks for liquid hydrogen that is used as a fuel in land vehicles as well as the testing methods required to ensure that a reasonable level of protection from loss of life and property resulting from fire and explosion is provided.

This part of ISO 13985~~International Standard~~ is applicable to fuel tanks permanently attached to land vehicles.

2 Normative reference(s)

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 13984: 1999, *Liquid hydrogen — Land vehicle fuelling system interface.*

3 Terms and definitions

For the purposes of this part of ISO 13985~~International Standard~~, the terms following apply.

3.1
burst pressure
pressure that causes the bursting of a ~~liquid~~inner vessel subjected to a constant increase of pressure during a destructive test

3.2
fill density
ratio, expressed as percentage, of the mass of liquid hydrogen in the ~~liquid~~inner vessel to the mass of water that the ~~liquid~~inner vessel would hold, on the basis of water density of 1000 kg/m^3

3.3
fire resistance
ability of a material or combination of materials used in fabrication of the fuel tank to prevent excessive pressure rise and assure resistance to rupture ~~buckling~~ when the fuel tank is tested as specified in 5.5.

3.4
fuel tank accessory ~~appurtenances~~
device~~s~~ connected to fuel tank openings for safety, control, or operating purposes

3.5
holding time
time, as determined by testing, that will elapse from filling loading until the pressure of the contents, under equilibrium conditions at ambient temperature, reaches the level of the lowest pressure control valve or pressure-relief valve setting of the fuel tank

3.6
liquidinner vessel
inner container of the fuel tank which actually contacts and holds the liquid hydrogen being transported

3.7
inspector
qualified person employed by a recognized independent national or international agency

3.8
liquid hydrogen
LH_2
hydrogen that has been liquefied, i.e. brought to a liquid state, either by chilling and compression or other means such as the magneto-caloric effect

3.9
lot
a group of liquidinner vessels, outer shells or fuel tanks successively produced, having the same size, configuration, specified material of construction, process of manufacture, equipment of manufacture and heat treatment or curing, and conditions of time, temperature and atmosphere during heat treatment or curing

3.10
maximum permissible operating pressure
MPOP
maximum effective gauge pressure permitted to be developed at the top of a loaded liquidinner vessel in its operating position. For vacuum-insulated fuel tanks, the maximum permissible operating pressure shall be established by subtracting the sum of 101,3 kilopascals and the hydrostatic head of lading from the maximum pressure difference between the inside and outside of the wall of the liquidinner vessel for which the wall is designed

3.11
outer shell
outer housing around the insulation which protects it against humidity and contamination and maintains a certain vacuum

3.12
same design
refers to a fuel tank made by the same manufacturer, to the same engineering drawings and calculations, to the same dimensions of length, diameter, and volume, of the same materials of construction, and with the same insulation system and to the same tolerances and quality control and quality assurance procedures

3.13
service pressure
the pressure at the top of the liquidinner vessel which is the pressure at which the fuel tank normally operates. This pressure shall not exceed the maximum permissible operating pressure

3.14
service temperature range
the temperature ranging from that of liquid hydrogen, i.e. - 253 °C to an assumed maximum ambient temperature of 85 °C 54 °C

3.15
vapour space
the space occupied by the saturated vapours of liquid hydrogen which are in equilibrium with the liquid hydrogen in the ~~liquid~~inner vessel

4 Design and construction of fuel tanks

4.1 General requirements

Liquid hydrogen fuel tanks for land vehicles shall be designed to be compatible with liquid and gaseous hydrogen and shall comply with the requirements of this part of ISO 13985~~International Standard~~.

Liquid hydrogen fuel tanks shall consist of an inner ~~liquid~~ vessel enclosed within an outer shell with appropriate insulation between the ~~liquid~~inner vessel and outer shell and having piping, valve supports and other ~~appurtenances~~accessories as specified in this International Standard.

~~The fuel tank holding time shall be established by the fuel tank manufacturer using the method described in 5.1.7. If more than one fuel tank is made to the same design, only one fuel tank shall be subjected to the full holding time test at the time of manufacture. However, each subsequent fuel tank made to the same design shall be performance tested during its first use. The holding time determined in this test may not be less than 90 % of the marked rated holding time.~~

The fuel tank shall be designed so that it can be filled with liquid hydrogen to a maximum permitted fill density which will yield a vapour space below the inlet to the pressure relief valve equivalent to at least 2 % of the volume of the fuel tank at the lowest set pressure of the transit pressure relief valve on stream.

A fuel tank filled with liquid hydrogen shall be capable of withstanding the fire resistance test described in 5.5.

4.2 Materials

All the materials or combination of materials used in the construction of the fuel tank components that are in direct contact with liquid hydrogen shall not be subject to low temperature embrittlement for the service temperature range and shall resist degradation due to hydrogen.

The manufacturer shall demonstrate and document that the materials used, including austenitic stainless steels or other materials that are proven to be equivalent, are suitable for this application over the service temperature range.

4.3 Inner ~~Liquid~~ vessel

4.3.1 Maximum permissible operating pressure

The maximum permissible operating pressure of the ~~liquid~~inner vessel of the fuel tank shall be established by the fuel tank manufacturer.

4.3.2 Wall thickness

The minimum thickness of the ~~liquid~~inner vessel shall not be less than 1,5 millimetres and shall be such that at no point will the combined static and dynamic stresses on a plane containing or normal to the longitudinal axis exceed 25 % of the minimum specified tensile strength of the material of construction. The static forces, loads, and stresses considered in this requirement shall take into account the weight of the fuel tank itself, its internal pressure at the maximum permissible operating pressure plus 101,3 kilopascals if the fuel tank is vacuum insulated, its maximum weight of contents, ~~and~~ the articles supported by the fuel tank, the stresses transferred from vehicle structure, not including the weight of structures supporting the fuel tank.

The dynamic stresses shall be considered including direct tensile stress due to a rearward acceleration force, tensile stress due to the bending moment of a rearward acceleration applied at the road surface, and tensile flexure stress using applicable static loadings, and, stresses due to external vacuum and internal pressure and other causes and the shear stresses in the plane in question, including direct vertical shear due to the static vertical loading, direct lateral shear due to a lateral accelerative force, ~~and~~ torsional shear due to a lateral accelerative force, applied at the road surface using applicable static loadings and the stresses transferred from vehicle structure.

4.4 Outer shell

4.4.1 Construction

An outer shell, of approximately the same shape as the ~~liquid~~inner vessel shall be used over the insulation. This outer shell shall be so constructed and sealed to maintain the integrity of the environment between the ~~liquid~~inner vessel and the outer shell.

4.4.2 Material of construction

All materials or combination of materials used for the construction of the outer shell of fuel tanks shall be compatible with the other environments and fluids found in a land vehicle environment such that the performance of the fuel tank is not degraded.

~~The material or combination of materials shall be rated fire resistant.~~

4.4.3 Minimum collapsing pressure

The outer shell shall be designed for a minimum collapsing pressure of 200 kilopascals differential.

4.5 Insulation

The interstitial space between the ~~liquid~~inner vessel and the outer shell may be evacuated after its filling with an adequate insulating material. The insulating material shall not be subject to corrosive attack by hydrogen, either in its gaseous or liquid state.

The insulation shall maintain any properties required by design during an emergency when exposed to fire, heat, cold, or water as applicable. The insulation shall be such that a fire external to the outer shell will not cause significant deterioration to the insulation's thermal conductivity by melting or settling as specified in 5.5.

The insulation material and outside covering shall be of adequate design to prevent insulation attrition under normal operating conditions.

The insulation system shall prevent the fuel tank pressure from exceeding the pressure relief valve set pressure within the marked rated holding time when the fuel tank is loaded with liquid hydrogen and exposed to an average ambient temperature of 65°C~~54 °C~~.

4.6 Fuel tank ~~appurtenances~~accessories

4.6.1 Pressure relief systems

4.6.1.1 Pressure relief system of the ~~liquid~~inner vessel

4.6.1.1.1 General requirements for pressure relief devices

The design, material, and location of pressure relief devices shall be suitable for the intended service.

The fuel tank shall be provided with a primary system of one or more pressure relief valves and a secondary pressure relief system of one or more rupture disks or pressure relief valves. The fuel delivery line to the propulsion system of the land vehicle shall be independent of the fuel tank pressure relief line.

The primary system of pressure relief valves shall be set to operate at a pressure not higher than 110 % of the maximum permissible operating pressure of the fuel tank. The secondary pressure relief system shall be set to operate as follows:

a) The Rrupture disks shall be set to operate not below 120 % and not more than 150 % of the maximum permissible operating pressure.

b) Pressure relief valves used in the secondary pressure relief system shall be set to operate at a pressure not higher than 136 % of the maximum permissible operating pressure.

Each pressure relief device shall be designed and located to minimize the possibility of tampering. If the pressure setting or adjustment is external to the pressure relief valve, this adjustment shall be sealed.

Each pressure relief device shall have direct communication with the vapour space of the fuel tank at the mid length of the top centreline and shall be mounted so as to remain at ambient temperature prior to operation.

The pressure relief system shall be arranged to prevent the accumulation of foreign material between the pressure relief devices and the atmospheric discharge opening. The arrangement shall not impede flow through the system.

The pressure relief valves shall, after discharge, close at a pressure higher not lower than 10 % below the pressure at which discharge starts or the maximum permissible operating pressure of the fuel tank, whichever is higher. and They shall remain closed at all lower pressures.

When operation of pressure build-up coils, or other conditions imposed by the service can produce pressures in excess of the maximum permissible operating pressure of the fuel tank, pressure relief valves shall be provided that are capable of preventing the development of fuel tank pressure in excess of 120 % of the maximum permissible operating pressure.

4.6.1.1.2 Flow capacities of pressure-relief devices

The minimum required flow capacity of the pressure relief devices shall be calculated using formula 1 if the fuel tank insulation is will be destroyed below 922 K:

$$Q_a = \frac{4{,}665 \times 10^4 \; A^{0{,}82}}{L} \sqrt{ZT} \qquad (1)$$

or the formula 2 if the fuel tank insulation will remains in place at 922 K:

$$Q_a = \frac{0{,}476\,8\,(922 - T)\; U A^{0{,}82}}{L} \sqrt{ZT} \qquad (2)$$

where

Q_a is the flow capacity of the pressure relief device(s) required at the applicable flow rating pressure and 15 °C, expressed in cubic metres per hour (m^3/h);

A is the arithmetic mean of the inner and outer surface areas of the fuel tank insulation, expressed in square metres (m^2). For fuel tanks with insulation which will not remain in place at 922 K, surface area of the liquidinner vessel shall be used;

Z is the compressibility factor at the temperature corresponding to the flow rating pressure. When *Z* is not known, the conservative value 1,0 should be used;

T is the temperature of hydrogen at flowing conditions, which shall be established based on the pressure set point of the pressure relief device plus the allowable accumulation pressure, expressed in degrees Kelvin (K);

L is the latent heat of hydrogen at the flow rating pressure, expressed in kilojoules per kilogram (kJ/kg);

U is the overall heat transfer coefficient of the fuel tank insulating material when saturated with gaseous lading or air at atmospheric pressure, whichever is greater, expressed in $kJ/(h \cdot m^2 \cdot °C)$. The value of *U* may be determined at the mean temperature of the insulation. *U* may be calculated as the thermal conductivity of the insulation, if the insulation is fully effective for conduction, convection, and radiation heat transfer for an external temperature of 922 K and an internal temperature corresponding to the flow rating pressure. Vacuum space, gas space, or space occupied by the deteriorated insulation shall not be included in the thickness of the insulation. The effectiveness of these spaces or deteriorated insulation in reducing conduction, convection, or radiation heat transfer may be evaluated separately and included in the overall heat transfer coefficient, *U*, using methods found in published heat transfer literature. Deterioration of the insulation can be caused by the following:

a) moisture condensation;

b) air condensation;

c) increase in density of the insulation due to sudden loss of vacuum;

d) degradation due to heat.

The minimum required total flow capacity of the primary system of pressure relief valves shall be calculated using the applicable formula above for a flow rating pressure not to exceed 120 % of the maximum permissible operating pressure of the fuel tank.

The minimum required total flow capacity of the secondary system of pressure relief devices shall be calculated using the formula above for a flow rating pressure not to exceed 150 % of the maximum permissible operating pressure of the fuel tank

~~**4.6.1.1.3Thermal expansion relief valves**~~

~~A thermal expansion relief valve shall be installed as required to prevent overpressure in any section of a liquid or cold vapour pipeline that can be isolated by valves~~

~~Thermal expansion relief valves shall be set to discharge at or below 110 % of the maximum permissible operating pressure of the section of the line it protects.~~

~~Discharge from such valves shall be directed so as to minimize hazard to personnel and equipment.~~

4.6.1.2 Pressure relief system of the outer shell

The outer shell of fuel tank shall be protected by a suitable pressure relief device to release internal pressure. This pressure relief device shall function at a pressure not exceeding 172 kilopascals or the internal design pressure of the outer shell or the maximum external collapse pressure of ~~on~~ the ~~liquid~~inner vessel calculated with a safety factor of 2, whichever is less.

The total discharge area of outer shell pressure relief devices on a fuel tank shall be at least 0,341 4 mm^2/kg of water capacity of the fuel tank.

