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ISO/TC **197** Secretariat: **SCC**

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

Liquid hydrogen — Land vehicle fuel tanks —

Part 2:
Installation and maintenance

Hydrogène liquide — Réservoirs de carburant pour véhicules terrestres —
Partie 2: Installation et entretien

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.

Contents

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 13985-2 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 2: Installation and maintenance

1 Scope

This part of ISO 13985~~International Standard~~ specifies the requirements for the installation and maintenance of the refillable fuel 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 International Standard is applicable to fuel tanks~~ are 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 and definitions given in ~~following~~ ISO 13985-1 and the following apply.

3.1
boil off management system
system which renders boil off harmless in normal conditions

3.2
boil off system
system that in normal conditions vents the boil off gas before the pressure of the contents reaches the level of the lowest pressure-relief valve setting of the fuel tank

4 Installation of fuel tanks

4.1 General requirements

Liquid hydrogen fuel tanks shall be installed so that any release of gaseous hydrogen is directed away from the driver or passenger compartment of the land vehicle preferably above or adjacent to these compartments. All connections to the fuel tank shall be external to, or sealed and vented from, these compartments.

Each fuel tank shall be mounted in a location to minimize damage from collision to the fuel tank itself and its ~~appurtenances~~accessories. No part of a fuel tank or its ~~appurtenances~~accessories shall protrude beyond the sides of the land vehicle at the point where it is installed. The installation of the fuel tank shall be such that it provides protection from impact, road debris, tools, or other incidental impact that could compromise the integrity of the tank.

The land vehicle fuel system shall be installed with as much road clearance as practical but not less than the minimum road clearance of the vehicle when loaded to its gross vehicle weight rating. This minimum clearance shall be measured from the lowest part of the fuel system.

No portion of the fuel tank or fuel tank ~~appurtenances~~accessories shall be located ahead of the front axle or behind the rear bumper mounting face of a land vehicle. Fuel tank valves shall be protected from physical damage using the land vehicle structure, valve protectors, or a suitable metal shield.

The fuel tank weight shall not be supported by outlet valves, manifolds, or other fuel connections.

Fuel tanks shall not be installed so as to adversely affect the driving characteristics of the land vehicle.

Each fuel tank shall be secured to the land vehicle body, bed, or frame to prevent damage from road hazards, slippage, loosening, or rotation using a method capable of withstanding a static force in the six principal directions (right↔left, backward↔forward, up↔down) of 8 times the weight of the full liquid hydrogen fuel tank with a maximum displacement of 13 millimetres.

Each fuel tank in a rack shall be secured to its cradle in such a manner that it is capable of withstanding a static force applied in the six principal directions (right↔left, backward↔forward, up↔down) of 8 times the weight of the liquid hydrogen full fuel tank with a maximum displacement of 13 mm.

Fuel tank shall be located more than 200 mm from any unshielded source of direct heat.

Any land vehicle compartment housing the liquid hydrogen fuel tank shall be equipped with a hydrogen detection system that sounds an audible alarm if the level of gaseous hydrogen exceeds 20 % of the lower flammability limit.

4.2 Installation of pressure relief devices and venting systems

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.

The pressure relief valves shall, after discharge, close at a pressure higher than 10 % below the pressure at which discharge starts. They shall remain closed at all lower pressures.

All pressure relief devices and connections between pressure-carrying components installed within a closed compartment shall be vented to the outside of the land vehicle in a suitable location. The fuel delivery line to the propulsion system of the land vehicle shall be independent of the fuel tank pressure relief line.

Pressure relief systems shall be arranged to discharge upward to the open air. The vent outlets of the venting system shall not terminate in the land vehicle engine compartment nor into a wheel well.

The venting system for the discharge of pressure relief devices (pressure relief device channels) shall be constructed of metallic tubing with welded fittings and shall be secured at the outer end.

A vent shall not restrict the operation of a pressure relief device or pressure relief channel. The vent line shall rise continuously and shall not contain any traps where water or other impediments to the flow of the venting gas can collect.

Vent outlets shall be protected by caps, covers, or other means to keep water, dirt, and insects from collecting in the lines. Protective devices shall not restrict the flow of gas.

A fuel tank, when located in a land vehicle compartment capable of accumulating hydrogen, shall be installed such that:

a) The pressure relief device for the protection of the fuel tank is installed in the same land vehicle compartment as the fuel tank;

b) The discharge from a pressure relief device referred to in (a) above is:

1) vented to the outside through a smooth walled metallic tube no smaller than the outlet diameter of the pressure relief device, and

2) located so that the vent opening will not be blocked by debris thrown up from the road, such as snow, ice, mud, or otherwise affected by the elements.

4.3 Installation of thermal 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 life and property~~personnel and equipment~~.

4.4 Installation of piping

Pipes, rigid tubing, flexible metallic hoses, fittings, gaskets, and packing material shall be compatible with liquid hydrogen under the service conditions.

~~Liquid hydrogen piping shall be fabricated and tested in accordance with the requirements specified below:~~

The bursting strength of all pipes, ~~, valves,~~ fittings, ~~and~~flexible metallic hoses and their connections shall be at least 4 times the maximum permissible operating pressure of the inner vessel and not less than 4 times the pressure to which they shall be subjected in normal service by the action of a pump or other device, the action of which could subject portions of piping to pressures greater than the inner vessel's maximum permissible operating pressure.

~~Flexible metallic hoses, flexible tubing, and their connections shall have a design burst pressure of at least 4 times the maximum permissible operating pressure.~~

Means shall be provided to minimize exposure of personnel to piping and to prevent air condensate from contacting piping, structural members and surfaces not suitable for cryogenic temperatures. Insulation shall maintain any properties that are required by design, during an emergency when exposed to fire, heat, cold, or water as applicable. It shall be designed to have a vapour-tight seal in the outer covering to prevent the condensation of air and subsequent oxygen enrichment within the insulation. The insulation material and outer covering shall also be of adequate design to prevent attrition of the insulation due to normal operating conditions.

Metallic hoses shall be vacuum jacketed or insulated to reduce heat input and to prevent the condensation of atmospheric air. The jacket design shall consider the inner line's thermal flexibility and allow the jacket to follow its natural thermal displacement.

Pipes, flexible metallic hoses, ~~tubing,~~ fittings, and other piping components shall be capable of withstanding a hydrostatic test of at least 1,5 times the maximum permissible operating pressure without structural failure.

Piping shall be joined by methods that permanently seal the joints to prevent hydrogen leakage, ~~permeation to the outside~~ use sealants and joining materials that prevent permeation and that will not degrade over time due to vibration and impact caused by land vehicle motion.

Where necessary to prevent abrasion, fuel lines passing through a panel shall be protected by grommets or similar devices.

Reasonable clearance shall be provided for the fuel lines passing close to hot components.

Fuel lines shall be mounted, braced, and supported to minimize vibration and protected against damage, corrosion, or breakage due to strain or wear. A fuel line shall be supported at least every 600 mm.

A bend in piping or tubing shall be prohibited where such a bend weakens the pipes or tubing.

A joint or connection shall be located in a readily accessible location.

4.5 Installation of valves

4.5.1 Valves

Valves, valve packing, and gaskets shall be suitable for hydrogen over the full range of pressures and temperatures to which they may be subjected under normal operating conditions.

The design of the valve shall be such that the removal of the valve stem without removing the complete valve bonnet or disassembling the valve body is not possible.

Each valve shall be designed and constructed for a rated pressure and the service temperature range not less than the inner vessel maximum permissible operating pressure or the maximum permissible operating pressure of the section of piping where the valve is used, whichever is higher.

The bursting strength of all valves shall be at least 4 times the maximum permissible operating pressure of the inner vessel and not less than 4 times the pressure to which they shall be subjected in normal service by the action of a pump or other device, the action of which could subject portions of piping to pressures greater than the inner vessel's maximum permissible operating pressure.

4.5.2 Shutoff valves

~~Every fuel tank shall be equipped with a~~ The manual or normally closed remotely actuated shutoff valve connected directly to the fuel tank shall be ~~and~~ installed in a readily accessible location that will permit isolation of the fuel tank from the remainder of the land vehicle fuel system.

No shutoff valve shall be installed between the pressure relief devices and the fuel tank. However, in cases where two or more pressure relief valves are installed on the same fuel tank, a shutoff valve may be used where the arrangement of the shutoff valve or valves is such as always to ensure full required flow capacity through the pressure relief devices opened to the inner~~liquid~~ vessel.

~~4.5.3Automatic shutoff valves~~

An automatic shutoff valve shall be provided in the system in order to prevent the flow of gaseous fuel to the land vehicle engine when the engine is not running even if the ignition is switched on.

Where multiple fuel systems are installed on the land vehicle, automatic shutoff valves shall be provided, as necessary, to shut off the fuel not being used.

NOTE - Electronic fuel injectors are considered to be automatic shutoff valves.

Shutoff valves shall have a rated service pressure not less than the maximum permissible operating pressure of the entire system and shall be capable of withstanding a hydrostatic test of at least 1,5 times the maximum permissible operating pressure without distortion. Valve seats shall be proven free of leaks greater than 10^{-4} Pa·m^3·s^{-1} when examined at a pressure of 1,25 times the maximum permissible operating pressure with a gas mixture containing at least 10 % helium using a method that guarantees the detection of leaks having a leak rate greater than 10^{-4}Pa·m^3·s^{-1}.

4.5.3 Backflow check valve

Fuelling systems that fill the fuel tank from the bottom shall be equipped with a backflow check valve that will prevent the return flow of gas or liquid from the fuel tank to the filling connection. A cold hydrogen return pipe shall be provided.

4.6 High liquid level alarm

The fuel tank shall be provided with a high-liquid level alarm. The alarm shall be set so that the operator will have sufficient time to stop the flow without exceeding the maximum permissible filling height and shall be located so that it is audible to personnel controlling the filling. A high-liquid level flow cut-off device, if used, shall not be considered as a substitute for the alarm.

4.7 Installation of pressure gauges

A pressure gauge located within a driver or passenger compartment of a land vehicle shall be installed in such a manner that no gas will flow through the gauge in the event of a failure.

A pressure gauge installed outside a driver or passenger compartment of a land vehicle shall be equipped with a limiting orifice, a shatterproof dial lens, and a body relief.

Pressure gauges shall be securely mounted, shielded, and installed in a protected location to prevent damage from vibration and unsecured objects.

4.8 Grounding

The fuel tank and associated piping shall be electrically bonded and grounded. Sufficient grounding connections shall be provided to prevent any measurable static charge from accumulating on any component. This grounding circuit shall be connected to a grounding knob and all the components should be electrically interconnected using stranded copper cables or a continuous metal frame, or both, so that every grounding knob acts as a common ground for every component.

4.9 Boil off under normal conditions

Boil off gases shall be vented off in a safe way or shall be rendered harmless by a boil off management system. If present, the boil off system and the boil off management system shall be designed to accept the boil off rate of the fuel tank under normal operating conditions. A warning system shall be incorporated to warn the driver in the event of the boil-off management system failure.

If the land vehicle is not equipped with a boil off management system, the vehicle shall not be allowed to be parked in an enclosed space or a roof-forming semi enclosed space except under safely controlled conditions regarding boil off. A warning label shall be installed in the field of vision of the driver.

5 Verification of the installation

5.1 Testing of pressure relief valves

Prior to its installation, each pressure relief valve shall be subjected to an air or gas pressure test to determine that the start-to-discharge pressure is within tolerances of the set pressure marked on the valve as required by the applicable standard.

CAUTION: In setting the valve, care must be taken that evidence of start-to-discharge is due to opening of the valve and not due to a defect.

After the start-to-discharge pressure test, the resealing pressure shall not be higher less than 90 % of the start-to-discharge pressure or the maximum permissible operating pressure of the fuel tank, whichever is higher .

5.2 Proof pressure test

A pneumatic test made at 1,25 times the maximum permissible operating pressure shall be performed. Due regard for all personnel should be taken because of the potential hazard involved in a pneumatic test. The fuel tank and associated piping shall be pressurized with air or an inert gas. All pressure-relief devices shall be blanked off for this test.

The test pressure shall be reached by gradually increasing the pressure to one-half of the test pressure. Thereafter, the test pressure shall be increased in steps of approximately 10 % of the test pressure until the test pressure has been reached. The pressure shall be maintained for a minimum time of 10 minutes. Then the pressure shall be reduced to a value equal to 80 % of the test pressure and held for a sufficient time to conduct the examination for leakage.

All fuel tank and associated piping failing to pass the pneumatic test, by showing evidence of leakage, distortion or other defects, shall be rejected.

5.3 Leakage test

Subsequent to the proof pressure test described in 5.2, the fuel tank and associated piping shall be subjected to a leakage test using a gas mixture containing at least 10% helium. The fuel tank, associated piping and all welded seams or bonded joints shall be proven free of leaks greater than 10^{-4} Pa·m^3·s^{-1} when examined at the maximum permissible operating pressure using a method that guarantees the detection of leaks having a leak rate greater than 10^{-4} Pa·m^3·s^{-1}.

Fuel tank and associated piping that leak shall be rejected.

5.4 Verification of holding time

~~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,~~ Eeach ~~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 marked on the fuel tank.

5.5 Grounding

Bonding and grounding of the fuel tank and associated piping shall be verified. The resistance to ground shall be less than 10 ohms.

6 Maintenance and periodic inspection

6.1 Repair of a fuel tank

Welding or bonding for the repair or alteration of a fuel tank shall comply with the documents under which the fuel tank was fabricated including inspection requirements. Other welding of metallic fuel tank shall be performed only on saddle plates, lugs, or brackets attached to the fuel tank by the fuel tank manufacturer.

Brazing and repair of the composite overwrap shall not be performed. Repaired fuel tanks shall be subjected to the non-destructive examination specified in ISO 13985-1, clause 6 before the fuel tank can be placed back into service.

6.2 Replacement of a pressure relief valve

If at any time it is necessary to break the seal for adjustment of a pressure relief valve, the valve shall be removed from service until it has been reset, ~~and~~ sealed and tested in accordance with 5.1. Any adjustment necessary shall be made by the manufacturer or other companies having competent personnel and adequate facilities for the repair, adjustment, and testing of such valves. The organization making such adjustment shall attach a permanent tag with the setting, capacity and date to the pressure relief valve.

6.3 Periodic in-service inspections

Each fuel tank as well as the performance of the control and safety devices shall be verified ~~inspected~~ at least every 42 months for damage and deterioration. The inspection shall be performed by a qualified person in accordance with the manufacturer's established re-inspection criteria.

Pressure relief valves shall be examined and tested at least every 42 months.

6.4 Fuel tanks involved in accidents

Fuel tanks which have been involved in vehicle impact and upon visual examination show visual indication of physical damage ~~subjected to the stress of vehicular accidents~~ shall be returned to the manufacturer and subjected to the non-destructive examination specified in ISO 13985-1, clause 6 ~~re-qualified~~ before the fuel tank can be placed back into service.

6.5 Fuel tanks involved in fire

Fuel tanks which have been subject to damage from excessive heat or to the action of fire shall be condemned and removed from service.

7 Marking and labelling

7.1 Marking of valves

The valve body shall be low stress stamped by the manufacturer to indicate the service ratings.

The presence of thea manual shutoff valve described in 4.5.2 shall be marked with the words "MANUAL SHUTOFF VALVE". Decals or stencils may be used. Marking shall be permanent and indelible.

7.2 Marking of hoses

Hoses and metallic hoses shall be distinctly marked by the manufacturer, either by a manufacturer's permanently attached tag or by distinct markings, indicating the manufacturer's name or trademark, applicable service identifier, and maximum permissible operating pressure.

7.3 Labelling of the land vehicle

7.3.1 Engine compartment

A label shall be located in the land vehicle engine compartment and be readily visible and shall include the following:

a) The wording: LH_2 FUELLED VEHICLE;

b) Maximum permissible operating pressure;

c) Manufacturer's Installer's name or company;

d) Fuel tank retest date(s) or expiration date;

e) Total fuel tank water volume in litres;

f) Test pressure;

g) Fuel tank's serial number;

h) The rated holding time marked on of the fuel tank as determined in 5.1.7 or a lesser value as may deemed appropriate.

7.3.2 Fuelling connection receptacle

A label shall be located at the fuelling connection receptacle of the land vehicle and shall include the following:

a) The wording: LH_2 FUELLED VEHICLE;

b) The warning: REFILL WITH LIQUID HYDROGEN (LH_2) ONLYHYDROGEN, REFRIGERATED LIQUID ONLY;

c)A reference to this International Standard.

The refuelling receptacle shall incorporate a means to prevent the entry of dust, water, and other foreign material. If the means used is capable of sealing system pressure, it shall be capable of being depressurized before removal.