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Title: Draft BS ISO 13984 Liquid hydrogen — Land vehicle fueling protocol.

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## Introduction

This draft standard is based on national and international discussions. Your comments on this draft are invited and will assist in the preparation of the consequent standard.

For international standards, comments will be reviewed by the relevant UK national committee before sending the consensus UK vote and comments to the international committee, which will then decide appropriate action. If the international standard is approved, it is usual for the text to be published as a British Standard.

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## UK Vote

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## Template for comments and secretariat observations

|                  |                        |
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| 1  | 2                                          | (3)                          | 4               | 5                                                                                                                                  | (6)                                                                      | 7                                                  |
|----|--------------------------------------------|------------------------------|-----------------|------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------|----------------------------------------------------|
| MB | Clause No./ Subclause No./Annex (e.g. 3.1) | Paragraph/ Figure/Table/Note | Type of comment | Comment (justification for change) by the MB                                                                                       | Proposed change by the MB                                                | Secretariat observations on each comment submitted |
|    | 3.1                                        | Definition 1                 | ed              | Definition is ambiguous and needs clarifying.                                                                                      | Amend to read '...so that the mains connector to which no connection...' |                                                    |
|    | 6.4                                        | Paragraph 2                  | te              | The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK. | Delete reference to UV photometer.                                       |                                                    |



# DRAFT International Standard

## ISO/DIS 13984

### Liquid hydrogen — Land vehicle fueling protocol

ICS: 43.060.40; 27.075

ISO/TC 197

Secretariat: **SCC**

Voting begins on:  
**2025-02-24**

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**2025-05-19**

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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](http://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](http://www.iso.org/iso/foreword.html).

This document was prepared by Technical Committee ISO/TC 197, *Hydrogen technologies*.

This second edition cancels and replaces the first edition (ISO 13984:1999), which has been technically revised.

The main changes compared to ISO 13984:1999 are as follows:

- updated scope
- normative references and definitions update
- alignment with common ISO 19880-1 requirements
- displacement of technical requirements to annexes
- introduction of fuelling process and protocols details
- creation of supporting annexes

A list of all parts in the ISO 13984 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](http://www.iso.org/members.html).

## Introduction

The focus of the document are liquid hydrogen fuelling protocols, however some technical requirements for the dispensing system and the fuelling station are also included, first to ensure the fuelling protocols can be implemented safely and with adequate equipment. Secondly the existing knowledge of the ISO 13984:1999 standard has been reviewed and adapted when relevant.

This International Standard has been prepared in coordination with the revision of ISO 13985. The fuelling protocols described in this document and the liquid hydrogen storage systems built according to ISO 13985 are thus intended to work together.

# Liquid hydrogen — Land vehicle fueling protocol

## 1 Scope

This document describes fuelling protocols for liquid hydrogen (LH<sub>2</sub>), defining the minimum design, installation and operation requirements for a safe, as well as fast, efficient and interoperable hydrogen transfer from the fuelling station to the vehicle fuel system.

This document applies to land vehicles of all types equipped with a liquid hydrogen storage system fulfilling ISO 13985 requirements. The protocols described in this document are currently limited to vehicles with storage system total internal volume equal to or comprised between 0,6 m<sup>3</sup> and 4 m<sup>3</sup>. Further hydrogen applications may apply the requirements of this standard. However, further specific requirements that can be necessary for the safe operation of such fuelling are not addressed in this document.

This document specifies the requirements for liquid hydrogen fuelling and dispensing systems, fuelling station - vehicle interface and vehicle storage system in order to minimise the risk of fire, explosion or any other hydrogen adverse effects to an acceptable level, especially during and after the fuelling process.

## 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 3864 (all parts), *Graphical symbols — Safety colours and safety signs*

ISO 7010, *Graphical symbols — Safety colours and safety signs — Registered safety signs*

ISO 7369:2020, *Pipework — Metal hoses and hose assemblies — Vocabulary*

ISO 10286:2021, *Gas cylinders — Vocabulary*

ISO 10893-4, *Non-destructive testing of steel tubes — Part 4: Liquid penetrant inspection of seamless and welded steel tubes for the detection of surface imperfections*

ISO 10893-6, *Non-destructive testing of steel tubes — Part 6: Radiographic testing of the weld seam of welded steel tubes for the detection of imperfections*

ISO 10893-7, *Non-destructive testing of steel tubes — Part 7: Digital radiographic testing of the weld seam of welded steel tubes for the detection of imperfections*

ISO 10893-8, *Non-destructive testing of steel tubes — Part 8: Automated ultrasonic testing of seamless and welded steel tubes for the detection of laminar imperfections*

ISO 10893-10, *Non-destructive testing of steel tubes — Part 10: Automated full peripheral ultrasonic testing of seamless and welded (except submerged arc-welded) steel tubes for the detection of longitudinal and/or transverse imperfections*

ISO 11484, *Steel products — Employer's qualification system for non-destructive testing (NDT) personnel*

ISO 13985, *Liquid hydrogen — Land vehicle fuel tanks*

ISO 14001, *Environmental management systems — Requirements with guidance for use*

ISO 14687, *Hydrogen Fuel Quality*

ISO 17398, *Safety colours and safety signs — Classification, performance and durability of safety signs*

ISO 17636 (all parts), *Non destructive testing of welds — Radiographic testing*

ISO 19880-1:2020, *Gaseous hydrogen — Fuelling stations — Part 1: General requirements*

ISO 21012, *Cryogenic vessels — Hoses*

ISO 21013-1, *Cryogenic vessels — Pressure-relief accessories for cryogenic service — Part 1: Reclosable pressure-relief valves*

ISO 21013-2, *Cryogenic vessels – Pressure-relief accessories for cryogenic service — Part 2: Non-reclosable pressure-relief devices*

ISO 21013-3, *Cryogenic vessels – Pressure-relief accessories for cryogenic service — Part 3: Sizing and capacity determination*

IEC 60079-14, *Explosive atmospheres - Part 14: Electrical installations design, selection and erection*

IEC 60417, *Graphical symbols for use on equipment - Overview and application*

ECE/TRANS/180/Add.13/Amend.1 UN GTR No. 13, *UN Global Technical Regulation on Hydrogen and Fuel Cell Vehicles*

ASME B31.12, *Pressure piping code*

CGA G-5.4, *Hydrogen Piping Systems at User Locations*

### 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 7369 and ISO 10286 and the following 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

##### **ambient temperature**

unregulated temperature of the air

#### 3.2

##### **backgas**

gaseous hydrogen flowing back from the vehicle to the *fuelling station* (3.19) during the *fuelling process* (3.17)

#### 3.3

##### **breakaway device**

device on the *fuelling hose* (3.15) that disconnects the hose from the *dispenser* (3.7) or the vehicle when a tension, load, stress or displacement limit is exceeded and blocks the flow of hydrogen from the dispenser, e.g. if the vehicle moves away with the fuelling hose connected to the vehicle

#### 3.4

##### **check-valve**

valve which allows fluid to flow in only one direction

#### 3.5

##### **control valve**

valve electronically or pneumatically controlled that enables and disables the hydrogen flow

Note 1 to entry: the control system provides necessary inputs and signals to the valve.

### 3.6

#### **connector**

matching parts (such as male and female parts) that can be put together to form a “connection” which permits the transfer of fluids, electric power, or control signals

[SOURCE: ISO 19880-1:2020, 3.12, modified — Notes have been removed.]

### 3.7

#### **dispenser**

equipment in the *dispensing system* (3.9), including the *dispenser cabinet(s)* (3.8) and support structure, that is physically located in the fuelling area

Note 1 to entry: The hydrogen dispenser typically includes, as a minimum, the *fuelling assembly* (3.14), required temperature and pressure instrumentation, filters, and the user interface to conduct vehicle fuelling.

Note 2 to entry: The manufacturer of the hydrogen dispenser can elect to include additional equipment in the dispenser, including the possibility of all equipment in the dispensing system.

[SOURCE: ISO 19880-1:2020, 3.13]

### 3.8

#### **dispenser cabinet**

protective *housing* (3.24) that encloses process piping and can also enclose measurement, control and ancillary *dispenser* (3.7) equipment

[SOURCE: ISO 19880-1:2020, 3.14]

### 3.9

#### **dispensing system**

system downstream of the hydrogen supply system comprising all equipment necessary to carry out the vehicle fuelling operation, through which the liquid hydrogen is supplied to the vehicle and which transferred quantity may be measured

Note 1 to entry: Refer to ISO 19880-1 for details on the supply system.

### 3.10

#### **enclosure**

structure, protective *housing* (3.24), container, machine cabinet, etc. which encloses or partially encloses equipment of a station that may have access for maintenance but is not intended to be occupied

[SOURCE: ISO 19880-1:2020, 3.18, modified — Notes have been removed.]

### 3.11

#### **factory acceptance testing**

##### **FAT**

tests performed in the factory on *fuelling station* (3.19) equipment or systems to verify functionality and/or integrity prior to shipment to the site, (or an appropriate alternative type acceptance methodology)

[SOURCE: ISO 19880-1:2020, 3.21]

### 3.12

#### **mass flowrate**

##### **flowrate**

flowrate measured in g/s unless otherwise stated

### 3.13

#### **fuelling**

transfer of hydrogen fuel from the *fuelling station* (3.19) to the *LHSS* (3.24)

### 3.14

#### **fuelling assembly**

part of the *dispenser* (3.7) providing the interface between the *fuelling station* (3.19) and the vehicle - an assembly consisting of a hose *breakaway device* (3.3), a hose(s), a *nozzle* (3.27) and connections between these components

[SOURCE: ISO 19880-1:2020, 3.26, modified — Notes have been removed.]

### 3.15

#### **fuelling hose**

flexible tube designed for dispensing liquid hydrogen to vehicles through a fuelling *nozzle* (3.27)

Note 1 to entry: ISO 7369, ISO 10380 and ISO 21012 provide example of hoses

### 3.16

#### **fuelling pad**

area with special construction requirements adjacent to the hydrogen *dispensers* (3.7), where customers park their vehicles during fuelling

[SOURCE: ISO 19880-1:2020, 3.28]

### 3.17

#### **fuelling process**

procedure to implement vehicle fuelling according to parameters defined in the *fuelling protocol* (3.18), including design, hardware, as well as control and operation rules of hardware of the *hydrogen fuelling station* (3.19)

### 3.18

#### **fuelling protocol**

specification of minimum safety and performance requirements of the *fuelling process* (3.17), allowing interoperability between *hydrogen fuelling station* (3.19) and vehicle

### 3.19

#### **hydrogen fuelling station**

##### **fuelling station**

facility for the dispensing of liquid hydrogen vehicle fuel, often referred to as a hydrogen refuelling station (HRS) or hydrogen filling station, including the supply of hydrogen, and hydrogen pump, storage, and *dispensing systems* (3.9)

### 3.20

#### **fuelling station operator**

person or organisation responsible for the safe operation, maintenance and housekeeping of the *fuelling station* (3.19)

[SOURCE: ISO 19880-1:2020, 3.32]

### 3.21

#### **guard**

part of a machine specially used to provide protection by means of a physical barrier

Note 1 to entry: depending on its construction, a guard can be called casing, cover, screen, door, enclosed guard, etc.

[SOURCE: ISO 19880-1:2020, 3.33]

### 3.22

#### **hose assembly**

assembly which includes the hose and end connections

**3.23****housing**

*guard* (3.21) or *enclosure* (3.10) for operating parts, control mechanisms, or other components, that need not be accessible during normal operation

[SOURCE: ISO 19880-1:2020, 3.40]

**3.24****liquefied hydrogen storage system****LHSS**

system that stores the liquid hydrogen, allows its fuelling from a dispenser, allows its feeding to a hydrogen conversion system and maintains integrity and safety. It is composed of the liquefied hydrogen storage container(s), pressure relief devices, shut-off devices, check-valves, boil-off valve and interconnection pipings and fittings between the above components, on-board vehicle, as defined in ISO 13985

**3.25****liquid hydrogen****LH2**

hydrogen that has been liquefied, i.e. brought to a liquid state

**3.26****subcooled liquid hydrogen**

*liquid hydrogen* (3.25) at a pressure-temperature condition below the saturation temperature for this pressure.

Note 1 to entry: variation of either pressure, temperature or both can bring a saturated liquid to a subcooled liquid state.

Note 2 to entry: [Figure 1](#) shows the saturation curve for hydrogen

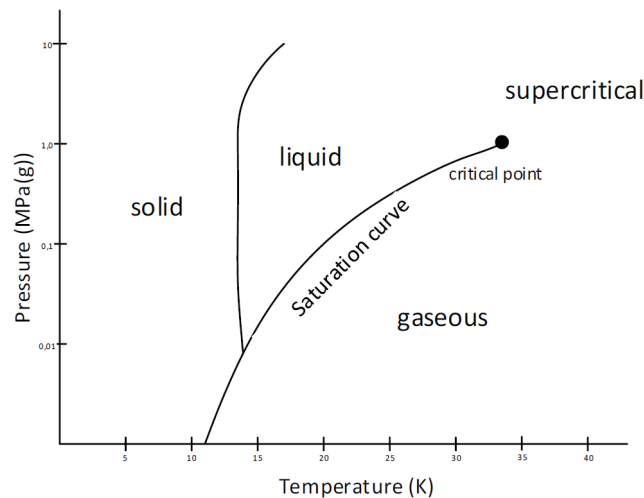


**Figure 1 — Phase diagram of hydrogen**

**3.27****nozzle**

device connected to a fuel *dispensing system* (3.9), which permits the quick connect and disconnect of fuel supply to the vehicle fuel system

[SOURCE: ISO 19880-1:2020, 3.53, modified — vehicle storage system to vehicle fuel system]

**3.28****pressure**

gauge pressure measured in MPa against atmospheric pressure unless otherwise stated

### 3.29

#### **design pressure**

pressure used for the calculation of the minimum characteristics for each component or sub-system in the system

Note 1 to entry: the design pressure should be not less than the pressure at the most severe condition of coincident internal or external pressure and temperature (minimum or maximum) expected during service.

### 3.30

#### **maximum allowable working pressure**

##### **MAWP**

means the highest pressure to which a component, a pressure container or a storage system is permitted to operate permanently under normal operating conditions

Note 1 to entry: further guidance on pressure terminology is included in [Annex D](#)

### 3.31

#### **maximum operating pressure**

##### **MOP**

highest pressure that is expected for a component or system during normal operation including anticipated transients

Note 1 to entry: Further guidance on pressure terminology is included in [Annex D](#)

[SOURCE: ISO 19880-1:2020, 3.47, modified — different notes]

### 3.32

#### **operating pressure**

pressure at which the piping system operates

Note 1 to entry: operating pressure should not exceed the maximum operating pressure

### 3.33

#### **target pressure**

##### **$P_{\text{target}}$**

*dispenser* (3.7) fuel pressure that the *fuelling protocol* (3.18) targets for the end of fuelling. The pressure measurement is as close as possible from the *hose assembly* (3.22)

Note 1 to entry: Further guidance on pressure terminology is included in [Annex D](#)

### 3.34

#### **pressure relief device**

##### **PRD**

reclosable or non-reclosable safety device that releases gases or liquids above a specified pressure value in cases of emergency or abnormal conditions

### 3.35

#### **qualified personnel**

personnel with knowledge or abilities, gained through training and/or experience as measured against established requirements, standards or tests, that enable the individual to perform a required function

[SOURCE: ISO 10417:2004, 3.13, modified — The word "characteristics" has been replaced with "knowledge".]

### 3.36

#### **receptacle**

device from the *vehicle fuel system* (3.41) which receives the *nozzle* (3.27)

[SOURCE: ISO 19880-1:2020, 3.64, modified — vehicle storage system to vehicle fuel system]

**3.37****site acceptance testing****SAT**

tests performed after installation of the *fuelling station* (3.19) at the site to verify functionality and/or integrity

[SOURCE: ISO 19880-1:2020, 3.75]

**3.38****standards development organisation****SDO**

industry- or sector-based standards organisations that develop and publish industry specific standards

Note 1 to entry: In some cases, international industry-based SDOs may have direct liaisons with international standards organisations. SDOs are differentiated from standards setting organisations (SSOs) in that SDOs may be accredited to develop standards using open and transparent processes.

Note 2 to entry: In the European Union, only standards created by CEN, CENELEC, and ETSI are recognised as European standards, and member states are required to notify the European Commission and each other about all the draft technical regulations. These rules were laid down in Directive 2015/1535/EU with the goal of providing transparency and control with regard to technical regulations.

[SOURCE: ISO 19880-1:2020, 3.77]

**3.39****fuelling station storage tank****storage tank**

liquid hydrogen reservoir, located at the *fuelling station* (3.19), to contain liquid hydrogen, which is then transferred to the *vehicle fuel system* (3.41)

**3.40****temperature**

temperature measured in K unless otherwise stated

**3.41****vehicle fuel system (VFS)****LHSS fuel system**

is an assembly of components used to store or supply hydrogen fuel to a fuel cell (FC) or internal combustion engine (ICE), according to GTR#13

Note 1 to entry: the fuel system typically includes one or more *LHSS* (3.24), receptacles, interconnecting lines, boil-off gas management system.

**4 Requirements****4.1 Hydrogen and cryogenic temperatures compatibility**

All components of the fuelling system which come in contact with liquid hydrogen and cryogenic gaseous hydrogen shall be compatible with and suitable for liquid hydrogen service and cryogenic gas flows, such as those associated with the handling of cryogenic gaseous hydrogen returning from the LHSS fuel system. They shall also be designed and qualified for the intended service life of the fuelling station.

Piping systems exposed to temperature fluctuations over the service temperature range shall be designed to withstand thermal expansion and contraction.

Consideration shall also be given to the possible condensation of air. Where prevention is not possible countermeasures such as dripping pans shall be used.

NOTE Guidance for material under cryogenic service is given in ISO/TR 15916, ISO 21010 or ISO 21028-1.

## 4.2 Material specifications

Material used in the manufacture of components for liquid hydrogen service shall have proven performance with hydrogen and cryogenic temperatures.

NOTE Guidance for material compatibility choices is given in ISO 21010 and ISO 11114-1.

## 4.3 Piping

Piping, valves, fittings, gaskets and sealants shall be suitable for hydrogen service at the temperatures and pressures involved.

Guidance on design, thickness definition, cyclic effects accommodation for piping are provided in [Annex A \(A.1.1\)](#).

## 4.4 Pressure relief devices

Liquid hydrogen systems and equipment shall be protected from over-pressure, e.g. by use of one or more PRD(s), or by other appropriate means.

Re-closing PRDs shall meet the requirements of ISO 21013-1 or an equivalent national/regional standard.

Non re-closing safety devices shall meet the requirements of ISO 21013-2 or an equivalent national/regional standard.

Sizing and capacity determination of liquid hydrogen system PRDs shall meet the requirements of ISO 21013-3 or be designed in accordance with a national/regional standard, such as a harmonised standard. The different behaviour of gaseous and liquid phases shall be taken in consideration.

These pressure-relief devices shall be set to discharge at or below the design pressure of the section of the pressure equipment they protect.

When fittings and piping are used on the upstream and/or downstream sides of pressure-relief systems, the passages shall be designed so that the flow capacity of the pressure relief systems will not be reduced below the capacity required for the pressure equipment on which the pressure-relief systems are installed. The opening through all piping and fittings shall have at least the same flow area as the inlet of the pressure-relief device to which it is connected. The nominal size of the discharge piping shall be at least as large as that of the pressure-relief device outlet. Oversized pressure-relief devices may be used without requiring all openings in their lines to have the same flow area, provided the required flow capacity is assured through the system.

Pressure relief devices shall be provided to prevent over-pressure, including overpressure by thermal expansion where liquid can be trapped.

Pressure relief devices and vent piping shall be designed or located so that moisture cannot collect and freeze in a manner which would interfere with proper operation of the pressure relief device.

Consideration should also be given in the design of the installation to facilitate the periodic inspection and testing of the pressure relief devices. Pressure relief valves shall be inspected and set point tested according to the manufacturer risk assessment and maintenance manual.

Further guidance on PRDs is provided in [Annex A \(A.1.2\)](#) as well as on pressure terminology in [Annex D](#).

## 4.5 Dispensing system

### 4.5.1 General requirements

An exemplary diagram of a fuelling station dispensing system is provided in [Figure 2](#).

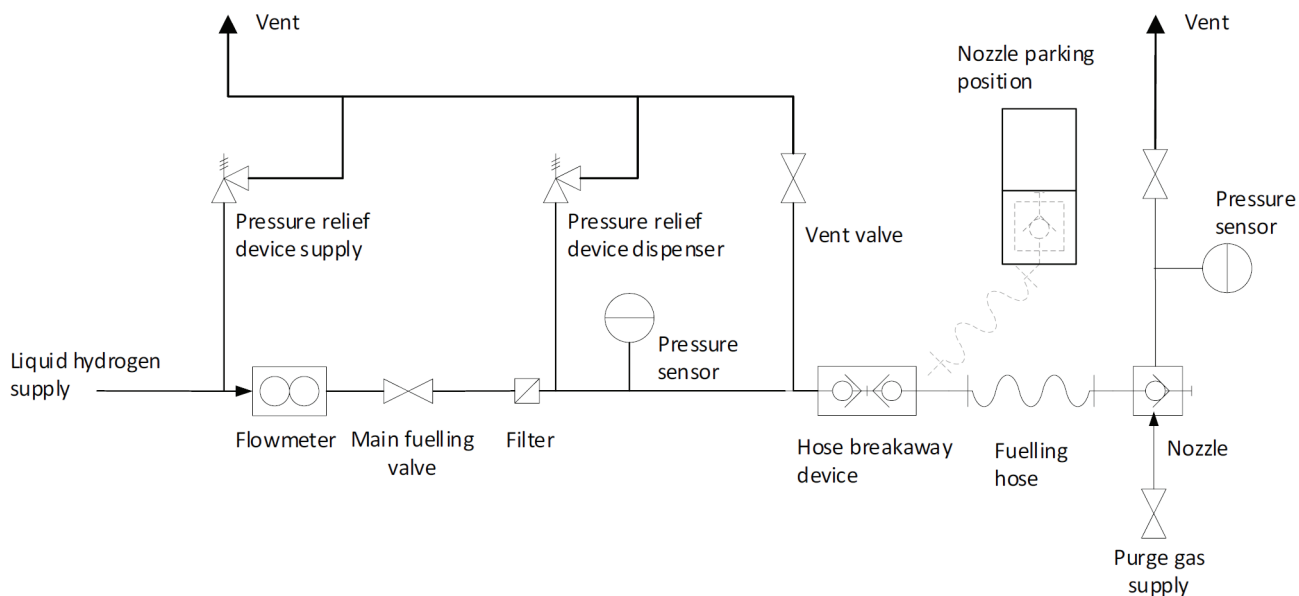


**Figure 2 — Exemplary illustration of a fuelling station dispensing system**

The dispensing system shall be equipped with a main fuelling valve capable of starting and stopping the flow of hydrogen transferred to the vehicle, according to the inputs of the control system. The main fuelling valve may additionally control the flowrate.

The dispensing system shall be equipped with a vent valve to handle hydrogen during the cool-down or purge process of the dispenser. It shall be capable of receiving the backgas from the vehicle in case of initial depressurisation of the vehicle fuel system. This valve should be of the normally open type, unless otherwise defined by risk assessment. Venting shall be directed to vent pipe termination point assessed and determined to be a safe location, i.e. accounting for ignition sources, as well as impact on persons, systems and structures.

Safety shut off valves in liquid hydrogen service shall be installed such that their actuators do not risk being blocked by accumulation of ice.

The dispensing system shall be capable of depressurising an LHSS, if required by the fuelling protocol specific starting pressure, while not exceeding its maximum operating pressure to initiate the fuelling process. The corresponding procedure is described in [Annex E](#).

The dispensing system components shall have an MAWP sufficient to handle backgas from the VFS. The associated PRD shall be set and designed accordingly. See [Annex D](#) for guidance on pressure levels.

The flow length between pressure sensor or transmitter and the beginning of the fuelling assembly shall not be greater than 1 m.

The dispensing system shall be equipped with a system capable of performing leak testing and purging of the connector before and after fuelling. The leak test and purge system shall be designed and have safeguards to prevent contamination or damage to the LHSS, e.g., appropriate pressure level. It is recommended to use helium for this purpose, but other gases, including hydrogen may be used, if proper measures are taken against freezing, contamination and build-up of dangerous flammable mixtures. The leak and purge system shall be designed, validated and maintained with a sufficient safety level, defined by the manufacturer risk assessment.

The dispensing system should be capable of performing a cool down procedure in case of warm LHSS at the beginning of the process. The corresponding procedure is described in [Annex E](#).

An emergency shutdown (ESD) system shall be provided that includes a shutoff valve for stopping liquid supply and shutting down transfer equipment. An ESD actuator, distinctly marked for easy recognition with a permanently affixed, legible sign, shall be provided near the dispenser and also at a safe, remote location.

The dispensing system shall be protected from vehicle collision damage, according to ISO 19880-1:2020 [5.3.7.4] and shall have means of detecting hydrogen leaks.

#### 4.5.2 Vehicle fuelling connectors

The main function of the fuelling connector is to enable the flow of liquid hydrogen from the fuelling station to the vehicle fuel system and in specific cases, allow the backgas flow from the vehicle fuel system to the fuelling station.

A vehicle fuelling connector shall provide for the reliable and secure connection of the VFS to a source of liquid hydrogen only. The connector shall be keyed, sized or located so that they cannot be cross-connected to compressed gaseous hydrogen, compressed natural gas, liquefied natural gas or any other fuel connectors, thereby minimising the possibility of connecting incompatible gaseous fluids or pressure levels. Consideration shall be given to pressure levels of other liquid hydrogen connectors.

The fuelling connector shall prevent escape of hydrogen, in either its gaseous or liquid form, when the connector is not properly engaged or becomes separated.

The fuelling connector shall comply with an approved LH2 connector standard and have an appropriate MAWP for the application. Until such a standard is available the latest state of the art shall be considered.

NOTE at the time of publication of this International Standard, ISO standardisation activities for the connector were ongoing.

The fuelling connector shall at minimum provide the following features:

- allow flow of hydrogen in both directions.
- have an automatic valve controlled by the fuelling station to isolate the nozzle.
- have the ability to open vehicle fuel system check-valves at the interface, with attention given to the necessary level of redundancy and independence of the check-valves.
- a means to purge the intermediate space between nozzle and receptacle, i.e. with purge gas and hydrogen.
- allow an automatic leak check to ensure proper locking mechanism and position of automatic valves and check-valves. Flow of liquid hydrogen shall only be allowed, once this test is successful.
- allow an automatic leak test during coupling, fuelling and decoupling.

Purging shall also be possible with the connector coupling mechanism decoupled or when coupled.

The fuelling connector either shall be equipped with an interlock device that prevents release while the line is open or shall have self-closing ends that automatically close upon disconnection.

When not in use, hoses shall be secured and the fuelling connector shall be protected from damage and freezing, e.g., in a storage bracket. The fuelling connector shall be prevented from coming in contact with the ground at any position between its storage position and the vehicle coupling, e.g., suspended by a tethering device.

The nozzle parts interfacing with the receptacle shall be kept dry and clean, free of ice and grease, while stored in the bracket. The bracket may include means of heating and drying cold surfaces of the nozzle and consideration shall be given to hydrogen concentration in the atmosphere of the holding bracket.

#### 4.5.3 Dispenser fuelling assembly

A dispenser fuelling assembly shall consist of, as a minimum, a hose breakaway device, a fuelling hose assembly, a nozzle, and connectors between these components. The dispenser fuelling assembly may also contain a backgas hose (and associated hose breakaway device). Auxiliary lines connected to the nozzle shall also be equipped with a hose breakaway device.

The total allowable leakage and/or permeation from the dispenser fuelling assembly throughout the specified life shall not present a hazard to people in the dispensing area. This amount should be determined by risk assessment. ISO 19880-1:2020 [8.4.4] provides guidance.

The fuelling assembly should be strong enough to withstand the loads (tensile and torsion) exerted by the user without damage.

The fuelling assembly shall provide sufficient electrical continuity such that [4.7](#) can be met.

The electrical resistance of the fuelling hose assembly, from end fitting to end fitting, shall be no greater than 100 k $\Omega$ .

NOTE the electrical resistance of the fuelling hose assembly can be limited to 1 k $\Omega$  for manufacturing quality control.

Exposure of people to extremely cold temperatures shall be considered in the risk assessment and countermeasures shall be provided when necessary. This is to prevent injury due to touching extremely cold fuelling assembly components or connections.

A hose breakaway device shall be provided as part of the fuelling assembly to prevent damages to the fuelling assembly, which would cause uncontrolled release of liquid hydrogen in the event of a drive-away, while the fuelling nozzle is still connected to the vehicle.

The axial disconnection force of the breakaway device should account for the following under all operating conditions:

- be less than 1 000 N, and
- be less than 70 % of the allowed extension force of the fuelling hose, and
- be less than 80 % of the allowed force in the hose with respect to the maximum allowed load of the fuelling connector without leak or damage.
- have a minimum force specified, to prevent unintended release during fuelling assembly manipulation.

NOTE the installation of the hose assembly on the dispenser might influence the direction of separation.

The hose breakaway device shall be installed according to the manufacturer specification such that when the fuelling hose is pulled, it will release without damage to the dispenser cabinet, fuelling hose assembly, the venting hose assembly (if used), the nozzle, or any other connection in the dispenser hose assembly.

NOTE damages which may occur after the disconnection, e.g. due to contact with the ground, are not intended here.

The hose breakaway manufacturer should define a maximum angle from the axis of the component for which disconnection force is applicable.

NOTE depending on the breakaway technology, installation requirements can vary to ensure that the release is working under all fuelling conditions, described in this International Standard.

It shall be ensured that the breakaway function is not affected by the shape and features of the dispenser, e.g. by protruding elements on which the hose can get caught, thereby preventing the hose breakaway device to function properly. The hose breakaway device on the fuelling line should incorporate shut-off features that isolate the dispenser side of the breakaway device, or both sides of the connection when uncoupled. At disconnection of the hose breakaway device, the station shall shut off hydrogen flow to the nozzle at or upstream of the breakaway and terminate the fuelling process.

The breakaway part attached on the nozzle side of the fuelling assembly shall be provided with a means to bleed/vent out cryogenic liquid potentially trapped in the separated part (e.g. hose) to prevent pressure increase beyond the maximum allowable pressure of this section. The design of the bleed/vent shall avoid jet release.

The fuelling hoses shall consist of vacuum or otherwise suitably insulated flexible hoses for the hydrogen to remain in its liquid form. The hoses shall be suitably equipped for the ventilation of any gaseous hydrogen

that may form. Flexible hoses used for liquid hydrogen delivery should comply with ISO 21012 and be designed for the conditions of use.

NOTE ISO 10380 provides general design rules for metallic flexible hoses.

The insulation shall maintain any properties that are required by design during an emergency when exposed to fire, heat, cold or water as applicable. Means to prevent air condensation shall be implemented.

Measures shall be implemented to detect a loss of vacuum in the hose. In case of vacuum loss, the hose should then be taken out of service by the responsible operator as soon as possible. The hose shall not be allowed to use until returned to specification defined by the hose manufacturer recommendation.

Gasket materials suitable for service with liquid hydrogen and that are properly sized shall be used for this service. Loose-fibre gasket material that can be readily fretted shall not be used, since the loose particles may contaminate the system. O-rings and O-ring grooves shall be matched properly for the design service conditions of low temperature and hydrogen exposure.

The maximum allowable working pressure (MAWP) of the fuelling assembly shall be rated equal to or greater than the storage tank design pressure or the discharge pressure of pumps or other devices, whichever is higher. Where dual hoses are used, provisions shall be made for gas recovery or venting.

Sharp bends and twists shall be avoided in the routing of flexible hose. The use of hoses in an installation shall be limited to a minimum.

#### 4.6 Installation, assembly and operation of equipment

[Annex A](#) provides guidance on installation of piping and hoses as well as on the equipment assembly and operations.

#### 4.7 Earthing and equipotential bonding

All conductive sections in the fuelling interface shall be equipotentially bonded to the rest of the system or earthed. Electrically isolated conductive sections shall not be used. Sufficient earthing conductivity shall be provided to prevent any measurable static electricity charge from accumulating on any component.

Electrical continuity for equipotential bonding and earthing shall be provided for the dispensing system including the fuelling assembly to prevent build-up of electrostatic charge.

The total electrical resistance for equipotential bonding and earthing the fuelling assembly shall be less than 1 M $\Omega$  between the vehicle end of the fuelling nozzle to earth.

Effectiveness of all earthing connections should be verified at an appropriate frequency that is consistent with risk assessment.

The electrical resistance between metallic parts connected or in contact together should be less than 10  $\Omega$ .

Both halves of a joint or flange connection shall be equipotentially bonded if there is an isolating seal (e.g. a polymer seal).

The equipotentially bonded hydrogen systems shall be earthed. The earthing system resistance shall be less than 1 M $\Omega$  to earth from any part within the hydrogen system.

All other conductive parts in hazardous areas that are not addressed above shall be connected to the equipotential bonding or earthing system or separately earthed in accordance with IEC 60079-14.

Other sources of static discharge shall be addressed, and measures shall be taken to remove them completely or reduce the probability of their occurrence.

Equipment and electrical sources that may unintentionally be in contact should have a common earthing.

The vehicle fuelling pad shall be made of non-combustible materials and designed to allow electrical earthing before the nozzle is connected to the vehicle.

The fuelling pad shall have a common earth connection with the station equipment. This requirement can be met by either:

- use of a concrete fuelling pad, or
- a material where an electrical resistance between the vehicle fuelling pad and the dispenser ground does not exceed  $100\text{ M}\Omega$ .

NOTE 1 this last requirement is valid based on the hypothesis that the resistance between the vehicle chassis and the tires-ground contact point does not exceed  $100\text{ M}\Omega$ <sup>[23]</sup>.

NOTE 2 if hydrogen is integrated into a multi-fuel station, other fuels can require more stringent grounding.

Figure 3 summarises the requirements:

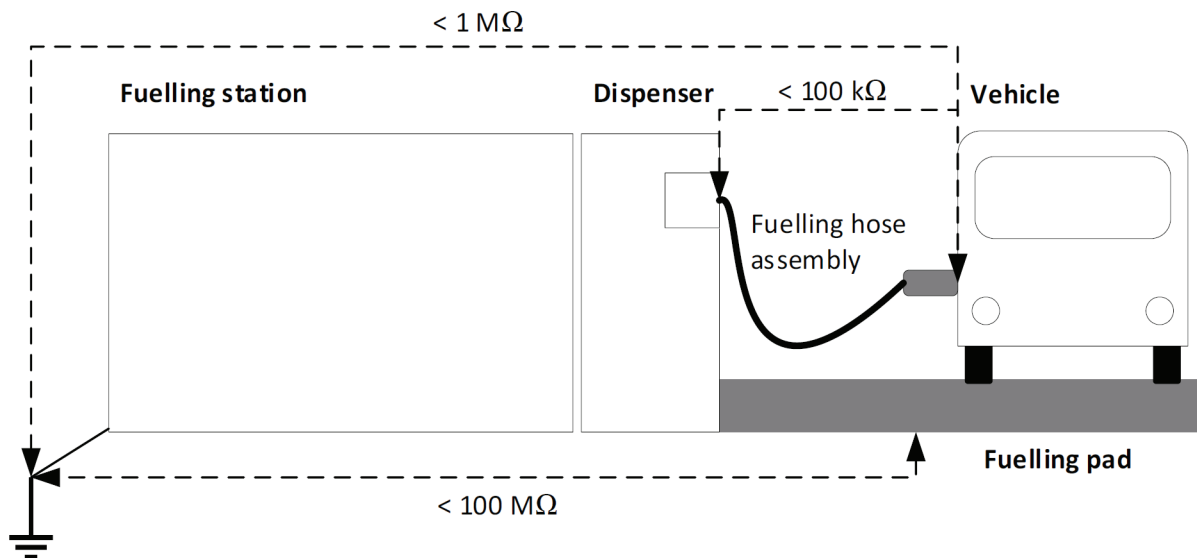


Figure 3 — Overview of earthing requirements

#### 4.8 Remote system control

If used, remote system control shall be designed and performed in a safe manner. ISO 19880-1:2020 [11.3] provides guidance on remote system control.

#### 4.9 Vehicle fuel system

Vehicle fuel systems fuelled according to the protocols in [Clause 5](#) and [Clause 6](#) shall be designed according to ISO 13985 and in particular comply to [Annex A](#) type LHSS requirements. They shall in addition comply with the GTR #13 requirements for LHSS, if adopted in the local regulation.

The rationale in [Annex C](#) provides the boundary conditions for the design of the vehicle fuel system. This accounts for basic design and especially the thermal mass of piping and components that are not maintained at cryogenic temperatures between fuelling and pressure ratings such as MOP and MAWP.

The vehicle fuel system shall be equipped with a receptacle according to an approved LH2 connector standard and with the appropriate MAWP for the application, that is compatible with the fuelling station nozzle. Until such a standard is available the latest state of the art shall be considered.

NOTE at the time of publication of this International Standard, ISO standardisation activities for the connector were ongoing.

## 5 Fuelling protocols requirements

### 5.1 General requirements

In order to ensure that the fuelling is conducted within the fuelling protocol process limits for vehicle LHSS, hydrogen dispensing systems shall either:

- use an approved published fuelling protocol, developed by a recognised standards development organisation (SDO), such as the protocols defined in [Clause 6](#)
- or
- use protocols, that have been approved by the manufacturers of each vehicle to fuel at that station using that protocol. The fuelling station operator shall take measures to prevent the fuelling of vehicles where fuelling protocols are not approved by the manufacturer(s) of the vehicles using the station.

The station manufacturer shall ensure the nozzle and other associated dispensing system components for each fuelling point are appropriate for liquid hydrogen and the fuelling protocol being used, including its defined maximum operation pressure.

The vehicle should have means to monitor the LHSS initial conditions. If these are not compatible with the fuelling protocol intended to be used, for example leakage detection or initial pressure too low, measures should be provided on the vehicle to prevent fuelling. Vehicle risk assessment shall determine these measures. Before fuelling and for the duration of fuelling the vehicle should additionally be secured against rolling.

Countermeasures shall be included to prevent vehicles that are not suitable for the fuelling protocol from being fuelled. VFS using LHSS developed according to Annex A of ISO 13985 are considered suitable for the fuelling protocols described in the following sections. The VFS will be equipped with specific connectors ensuring appropriate interoperability.

Before the fuelling, the station shall ensure the nozzle is released to the customer only under conditions preventing the transfer of moisture or ice to the vehicle fuel system. These conditions are specified by the manufacturer.

The station may either release the nozzle:

- after the customer has pressed the start button and the fuelling begins when the connection is automatically secured
- or first begin the fuelling after the nozzle is connected followed by the start button activation.

The station shall prevent any transfer of fluid until all locking mechanisms are secured and all station systems controls are ready.

In addition, the station should reduce the possible manipulation of the nozzle by the general public, i.e. through preliminary terminal authentication. The fuelling protocol shall include a pressure integrity check within the pre-fuelling (see [Clause 6](#)), which should also include the determination of the pressure of hydrogen within the vehicle prior to fuelling.

The fuelling protocol should be appropriate for the range of vehicle tank capacities that are intended to be fuelled.

The fuelling station shall be able to safely terminate the fuelling at any time during the fuelling process. The fuelling station shall avoid “stop and flow” control and especially ensure that vibrations from the supply, i.e. cryogenic pump, do not affect the safety of the dispensing system.

Further guidance on fuelling protocols is provided in ISO 19880-1 [8.2]

## 5.2 Single hose – target pressure based protocols

The goal of the protocols, described in this International Standard, is to provide safe and efficient fuelling for a large range of land vehicles with a single connector interface. This section describes the boundaries and applicability of the fuelling protocol, using a single hose and target pressure.

The protocols have been developed for vehicle fuel system from 0,6 m<sup>3</sup> up to 4 m<sup>3</sup>. [Annex C](#) provides the hypothesis and rationale for this range. Fuelling of volumes out of this range may be performed according to these protocols, but additional risk evaluations are required.

The fuelling protocols should enable fuelling with a single connection hose assembly and without having to handle backgas from the vehicle after the end of the pre-fuelling.

NOTE backgas should be handled before the main fuelling phase.

The fuelling time should be typically below 15 minutes, allowing up to 30 minutes for larger tank volumes. This corresponds to an average flow rate provided by the fuelling station up to 220 g/s.

The station may reference and indicate the used protocol with the following nomenclature:

LH2-XX(Y)-ZZ

where:

- LH2 designates a liquid hydrogen fuelling according to this International Standard
- XX designates the protocol and its maximum operating pressure, accounting for the connector type and target pressure, as presented in [Table 1](#)
- Y designates the difference between the maximum operating pressure of the protocol and the target pressure used, as presented in [Table 1](#)
- YYY designates the nominal mass flowrate of the fuelling station according to [Table 2](#)

**Table 1 — Protocol designation**

| Protocol description                                                             | Designation                                                                                                                                                                                                                                                                                                                         |
|----------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| — Single hose protocol, target pressure based following <a href="#">Clause 6</a> | XX(Y)                                                                                                                                                                                                                                                                                                                               |
| — Connector designed for the related maximum operating pressure                  | XX stands for the maximum operating pressure in barg and the related connector<br>(Y) stands for the difference: target pressure used – maximum operating pressure of the protocol in barg<br>Examples:<br>MOP = 15 barg and P <sub>target</sub> = 15 barg<br>— 15(0)<br>MOP = 10 barg and P <sub>target</sub> = 8 barg<br>— 10(-2) |
| Further protocols to be defined, e.g. two hoses, lower pressure connector, ...   | Currently no designation                                                                                                                                                                                                                                                                                                            |

Table 2 — Flowrate designation

| Nominal flowrate range in g/s                | Designation |
|----------------------------------------------|-------------|
| Min allowed by <a href="#">[6.1.3]</a> to 50 | SSF         |
| 50 to 100                                    | SF          |
| 100 to 200                                   | AF          |
| More than 200                                | FF          |

NOTE the specified flowrate corresponds to the average nominal flowrate, during the main fuelling phase and does not specify the components maximum flowrate. [\[6.1.3\]](#) provides additional information on the flowrate.

For example a fuelling protocol according to this International Standard with a maximum operating pressure of 1,5 MPa(g) and the related connector, a target pressure of 1,3 MPa(g) and an average flowrate of 210 g/s would be fully designated by LH2-15(-2)-FF, while the same protocol and with a target pressure of 1,5 MPa(g) and an average flowrate of 120 g/s would be fully designated by LH2-15(0)-AF.

Only pressure measured at the dispenser is used to terminate the fuelling without data communication between the fuelling station and the vehicle. The fuelling protocols are based on target pressure control criteria. Alternative criteria, such as liquid level, if available and reliable may be used by the fuelling station as control criteria.

The key boundaries and parameters of the fuelling protocols are given here:

- the minimum LHSS pressure at start-up shall be above 0,1 MPa(g). This is to identify a potentially empty or leaking vehicle fuel system.
- the maximum LHSS pressure at start up should be below 1,9 MPa(g). This is to avoid fuelling with open pressure relief devices and trespassing the MAWP of the LHSS.
- in case the starting pressure is higher than 0,9 MPa(g), the station should perform a depressurisation procedure to allow normal fuelling. [Annex E](#) describes a way of performing this procedure. This allows a proper fuelling process without reaching prematurely  $P_{\text{target}}$  while reducing the occurrence of vehicle fuel systems to be depressurised. An alternative trade-off between initial pressure, backgas amount and target fuelling density is possible and the station manufacturer should then define the optimum LHSS pressure before main fuelling. [Annex C](#) provides explanations on the boundary conditions.
- the ambient temperature range of the fuelling protocol is -40 °C to +50 °C. The fuelling station shall prevent fuelling out of this range.
- the fuelling station shall terminate the fuelling no later than when the defined target pressure by the protocol is reached.

The actions triggered by the different set point are described in [Clause 6](#). In addition, a detailed pressure nomenclature is provided in [Annex D](#).

### 5.3 Alternative protocols

Fuelling protocols for liquid hydrogen may alternatively be based on a two hoses configuration, with a return line for backgas.

The criteria used for terminating the fuelling may be different than a target pressure, for example the liquid hydrogen level in the LHSS, if made available to the fuelling station.

The detailed procedure for these alternative protocols is not addressed in this issue of this International Standard.

### 5.4 Manual control of dispensing

The user of the dispenser should have the ability to initiate and stop the automatic fuelling process from the dispensing area.

The station should decide based on risk assessment and existing minimum fuelling quantities under which conditions a user stop is permitted. In this case the LHSS will only be partially filled. This stop is different from an emergency stop.

## 5.5 Hydrogen specification

### 5.5.1 Hydrogen quality

LH<sub>2</sub> quality shall comply with ISO 14687 Type II Grade D. In order to prevent particulates contaminating the system, a wire mesh filter of 10 µm or less and compatible with liquid hydrogen service shall be installed upstream of the fuelling nozzle.

The fuelling station shall have means of minimising the ingress of non-hydrogen gases or liquids, which might freeze in the liquid hydrogen. The purge procedure described in [Clause 6](#) and [Annex E](#) is one way to fulfil this requirement.

### 5.5.2 Hydrogen supply condition

For single hose – target pressure based fuelling protocols, the fuelling station shall deliver subcooled liquid hydrogen to the vehicle fuel system after the pre-fuelling. In that intend the equilibrium pressure of the fuelling station storage tank during the fuelling should be below 0,35 MPa(g).

### 5.5.3 Hydrogen ortho-para ratio

In order to maximise the liquid hydrogen dormancy in the vehicle fuel system, the supplied LH<sub>2</sub> parahydrogen fraction should be maximised. As there is currently no reliable and affordable way of measuring the hydrogen ortho-para ratio, this is indicated for orientation. Requirements on measurements or verification of this ratio are not addressed in this International Standard.

NOTE ISO 14687 provides further information on parahydrogen fraction.

## 6 Single hose – target pressure based fuelling protocols

### 6.1 Introduction

The fuelling protocol consist of three main sequences the station shall implement in the following order:

1. pre-fuelling
2. main fuelling of the vehicle fuel system
3. post-fuelling

Other specific preliminary procedures may be necessary and are described in [Annex E](#).

The reference protocol described in this clause is called LH2-15(0) according to the nomenclature described in [\[5.2\]](#). Its target pressure  $P_{\text{target}}$  is set at 1,5 MPa(g).

An alternative version of the protocol may be used with a lower  $P_{\text{target}}$  and will be designated as LH2-15(-1) or further in this section.

#### 6.1.1 Pressure control

The dispenser shall be designed to withstand or handle maximum operating pressures of 1,5 MPa(g), whatever protocol and  $P_{\text{target}}$  is selected by the fuelling station. [Annex D](#) provides guidance on the pressure levels. The fuelling station shall evaluate the required reliability, redundancy and safety level appropriate on the pressure control.

The fuelling station shall terminate the fuelling as soon as possible but within 5 s in case the pressure exceeds the  $P_{\text{target}}$  or the lower limit of 0,1 MPa(g).

Fuelling stations implementing LH2-15(-1) or further may terminate the fuelling at a lower upper limit than 1,5 MPa(g).

NOTE the reference pressure drop between the dispenser pressure and the LHSS used for the definition of these protocols is set by a restriction of 14 mm diameter. It resulted in a pressure drop of less than 0,5 MPa(g) at 110 g/s flow rate and was confirmed by testing.

### 6.1.2 Temperature control

The fuelling protocols require the supply of subcooled liquid hydrogen to ensure the cool down of warm components along the supply line and the condensation of hydrogen in the LHSS. This allows the process to be performed, while avoiding prematurely reaching the target pressure. The fuelling station should target a total mass averaged temperature of the supplied liquid hydrogen below 26,5 K at the nozzle. This requirement is a design requirement, calculated for any fuelling with more than 10 kg of supplied liquid hydrogen and does not require measurement at the nozzle.

The fuelling station should consider means of monitoring the delivered temperature and define appropriate reaction in case of deviation.

NOTE the supply temperature is indirectly controlled and will thus vary, possibly above the proposed target, between steady state fuelling and transition phases.

### 6.1.3 Fuelling rates control

The flowrate control described for the protocols may be performed directly or indirectly via other parameters controls, i.e. pressure control or stroke rate. This accounts for different transfer technologies, e.g., cryogenic pump types and shall be sufficiently validated by the station manufacturer.

The reference maximum average mass flowrate is 220 g/s. [Annex C](#) provides further explanations on this parameter.

During the start of fuelling and end of fuelling phases of the main fuelling, the station shall ensure that the flowrate remains within  $\pm 10$  % of the defined range in [6.3.1](#) and [6.3.3](#). This is to ensure sufficient reaction time for the fuelling station in case of accelerated pressure changes during these phases.

During the steady state phase of the main fuelling, the fuelling station should maintain the nominal flowrate defined by the station manufacturer within  $\pm 10$  %. If these limits are exceeded for more than 5 s, the station shall be back within the limits within 10 s or terminate the fuelling as soon as possible but within 5 s.

In case the station is operated in a “reduced performance” mode, defined by the manufacturer, the fuelling station may fuel at lower flowrates with a minimum of 10 g/s.

The dispensing system shall be designed to handle excessive flow scenarios, if applicable and have the appropriate direct or indirect control of the flowrate.

For component design purpose the peak flowrate should be limited to 300 g/s.

### 6.1.4 Tolerances

The fuelling station shall account for its tolerance in applying the fuelling protocol. This is to ensure that the delivered fuel pressure, temperature, and mass flowrates remain in their defined boundaries.

The target pressures and set points are given with a tolerance of  $\pm 0,05$  MPa. The fuelling station shall trigger the required action within this tolerance.

## 6.2 Pre-fuelling

The pre-fuelling covers the preliminary actions before fuelling. This includes at least:

- vehicle earthing
- proper connection of the nozzle to the receptacle
- detection of the nozzle taken out of the holder
- locking of the nozzle receptacle connection
- automatic leak check
- automatic purge procedure
- initial pressure determination
- vent procedure
- any required action to ensure safe fuelling

Once the user has reached the fuelling station, connected the nozzle to the vehicle receptacle, pushing the start button will trigger the pre-fuelling. The station shall detect that the nozzle has been removed from its parking position and is properly connected to the receptacle. Alternative sequences are possible before the start of pre-fuelling, e.g. start button releases the nozzle and the next steps are detected automatically.

Measures shall be taken to avoid electrostatic risk, as described in [4.7](#). If additional measures are required, they shall occur at the beginning of the pre-fuelling.

The fuelling station shall then activate the automatic locking between nozzle and receptacle to secure the connection. Unlocking of the connection shall not be possible during the fuelling. The fuelling station should then perform a purge procedure and a leak test. Details on these actions are provided in [Annex E](#).

Integrity of the fuelling assembly and the vehicle connection shall be checked while the vehicle is connected. The integrity check shall detect a significant loss of pressure, or other indication of a leak, e.g., by use of a hydrogen detection system, and shut down in the event of detection of a leak.

If the pressure integrity check is not successful, the fuelling event shall be terminated. If necessary, an emergency shutdown should be executed.

The station shall then determine the LHSS initial pressure. The fuelling station shall only allow a fuelling if the LHSS pressure is comprised between 0,1 MPa(g) and 1,9 MPa(g). For pressures greater than the initial venting pressure  $P_{init\_vent}$ , e.g. 0,9 MPa(g), the fuelling station should depressurise the LHSS. This ensures that the pressure and temperature level requirements to perform a consistent fuelling are met.

$P_{init\_vent}$  may be reduced by the fuelling station for optimisation purposes and according to the fuelling protocol target pressure, i.e. LH2-15(-1) and further.

NOTE lower target pressure may require reducing further the initial LHSS pressure through venting. A detailed procedure for the depressurisation is provided as an example in [Annex E](#).

[Figure 4](#) illustrates the different process steps of the pre-fuelling.