



**International  
Standard**

**ISO 19885-1**

**Gaseous hydrogen — Fuelling  
protocols for hydrogen-fuelled  
vehicles —**

**Part 1:  
Design and development process for  
fuelling protocols**

**First edition  
2024-05**

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Published in Switzerland

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## Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see [www.iso.org/directives](http://www.iso.org/directives)).

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

A list of all parts in the ISO 19885 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

This document is intended to identify and describe requirements for the design and development of hydrogen dispenser fuelling protocols and address issues with current protocols with regard to their acceptance and thoroughness of verification as well as the safe implementation in dispenser systems.

This document is intended to coordinate with the ISO 19880 series with regard to road vehicles and, at the same time, address a more general need with the regard to fuelling a far broader range of vehicles. This document can help to address technical details of the fuelling process and will allow ISO 19880-1 to be streamlined and focus on basic requirements of the fuelling station.

This document is expected to be the first part in a series dealing with fuelling protocols for a broad range of vehicle applications.

Additionally, the requirements for the development process in this document are robust and can be considered for extension to other container-fuelling applications in the future.

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# Gaseous hydrogen — Fuelling protocols for hydrogen-fuelled vehicles —

## Part 1: Design and development process for fuelling protocols

### 1 Scope

This document addresses the design and development of fuelling protocols for compressed hydrogen gas dispensing to vehicles with compressed hydrogen storage of fuel.

The document does not address dispensing of compressed hydrogen gas to vehicles with hydride-based hydrogen storage systems as well as the dispensing of liquefied or cryo-compressed hydrogen.

This document is intended to be used for a wide range of applications, including, but not limited to, the following:

- light, medium, and heavy-duty road vehicles,
- motor bicycles and tricycles, carts, and trailers,
- off-road vehicles,
- fork-lift and other industrial trucks,
- rail locomotives and powered cars,
- airplanes and drones, and
- maritime ships, boats, and barges.

This document applies to a wide spectrum of development situations ranging from companies developing a fuelling protocol for their specific products or applications to standards development organizations (SDOs) developing a consensus-based fuelling protocol for a broad segment of the industrial or commercial market. Additionally, combinations between the two extremes are possible, where, for example, companies start design and development as a way of defining a proposal for new work by an SDO to complete development and publish the document as a consensus-based standard (including technical justification for compliance to this document).

This document defines requirements for the design and development of the fuelling protocols. These requirements can be integrated into the existing design and development processes to ensure that the fuelling protocol is fully verified and that the generated documentation is sufficient for the proper implementation and safe use of the fuelling protocols in dispensing systems for the targeted application.

In addition to addressing the design and development of fuelling protocols for general applications, [Annex A](#) provides specific requirements and information relative to fuelling protocols for road vehicles at public fuelling stations based on ISO 19880-1.

### 2 Normative references

The following documents are referred to in the text in such a way that some or all 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 19885-1:2024(en)

ISO 13849-1, *Safety of machinery — Safety-related parts of control systems — Part 1: General principles for design*

ISO 13849-2, *Safety of machinery — Safety-related parts of control systems — Part 2: Validation*

ISO 17268, *Gaseous hydrogen land vehicle refuelling connection devices, 2020*

ISO 19880 (all parts), *Gaseous hydrogen — Fuelling stations*

ISO 19881, *Gaseous hydrogen — Land vehicle fuel containers*

ISO/SAE 21434, *Road vehicles — Cybersecurity engineering*

ISO 26262, *Road vehicles — Functional safety*

IEC 60204-1, *Safety of machinery - Electrical equipment of machines - Part 1: General requirements*

IEC 61508, *Functional safety of electrical/electronic/programmable electronic safety-related systems*

IEC 61511, *Functional safety – Safety instrumented systems for the process industry sector*

IEC 62061, *Safety of machinery – Functional safety of safety-related electrical, electronic, and programmable electronic control systems*

### 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 19880-1 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

##### **basic process control system**

##### **BPCS**

system which responds to input signals from the process, its associated equipment, other programmable systems and/or an operator and generates output signals causing the process and its associated equipment to operate in the desired manner

Note 1 to entry: a BPCS does not perform any safety-instrumented functions with a claimed SIL  $\geq$  1.

[SOURCE: IEC 61511:2004, 3.2.3]

#### 3.2

##### **compressed hydrogen storage system**

##### **CHSS**

system designed to store compressed hydrogen fuel for a hydrogen-fuelled road vehicle, composed of a container, container attachments (if any), and all primary closure devices required to isolate the stored hydrogen from the remainder of the fuel system and the environment

Note 1 to entry: The above definition is specific to hydrogen road vehicles where the CHSS has one (and only one) container with dedicated primary closures devices. See [A.3](#).

Note 2 to entry: Hydrogen road vehicles typically have more than one CHSS. See *vehicle fuel system* ([3.27](#)).

Note 3 to entry: The CHSS can also include actuators, sensors, and electronics as deemed necessary by the vehicle manufacturer.

[SOURCE: ECE/TRANS/180/Add.13/Amend.1 UN GTR No. 13, UN Global Technical Regulation on Hydrogen and Fuel Cell Vehicles: 2023, 3.6]

### 3.3

#### **container**

pressure-bearing component on the road vehicle within the hydrogen storage system that stores the primary volume of hydrogen fuel in a single chamber or in multiple permanently interconnected chambers

Note 1 to entry: Cylinders and conformable containers are types of containers for road vehicles. See [A.3](#).

[SOURCE: ECE/TRANS/180/Add.13/Amend.1 UN GTR No. 13, UN Global Technical Regulation on Hydrogen and Fuel Cell Vehicles: 2023, 3.8]

### 3.4

#### **control system**

system which responds to input signals from the process and/or from an operator and generates output signals causing the process to operate in the desired manner

### 3.5

#### **data**

design characteristics and limits, process measurements (such as temperature, pressure, and flow), and associated calculated parameters of the interconnected dispensing system and vehicle fuel system during the fuelling process

Note 1 to entry: Calculated parameters can be based on, for example, interpolations of data tables such as fuelling tables for containers as well as formulas or equations involving other data.

#### 3.5.1

##### **dynamic data**

*data* ([3.5](#)) such as temperature and pressure measurements, and associated calculated parameters that are expected to change value with time during the fuelling process

#### 3.5.2

##### **static data**

*data* ([3.5](#)) such as design characteristics and limits and associated calculated parameters that are expected to remain constant with time during the fuelling process

### 3.6

#### **dispenser**

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

Note 1 to entry: The hydrogen dispenser typically includes the fuelling assembly, 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 include additional equipment in the dispenser, including all equipment in the dispensing system.

### 3.7

#### **dispensing system**

system downstream of the hydrogen supply system comprising all equipment necessary to carry out the vehicle fuelling operation, through which the compressed hydrogen is supplied to the vehicle

### 3.8

#### **fuelling envelope**

required design space for the fuelling protocol that captures extreme combinations of hydrogen fuelling and storage systems on vehicles to be fuelled, the ambient and operating conditions of the vehicle during operation and dispensing, and the capabilities and limitations of the vehicle fuel system and dispensing systems

### 3.9 fuelling protocol

technical descriptions, instructions, or constructs that define how the dispensing of compressed gaseous hydrogen to storage systems on vehicles is to be conducted

Note 1 to entry: The *fuelling protocol* serves as the basis for defining control strategies and algorithms for implementation in the *BPCS* (3.1) hardware and software of the dispensing control system

Note 2 to entry: *Fuelling protocols* can range from simple descriptions that can be performed in hardware to complex programmable control functions using prescribed values, tables, and/or reduced-order models as well as conventional process controls such as feedforward-feedback and predictor-corrector control functions.

### 3.10 fuelling station

hydrogen fuelling station  
hydrogen refuelling station

#### HRS

facility for the dispensing of compressed hydrogen vehicle fuel, including the supply of hydrogen, and hydrogen compression, storage, and dispensing systems

### 3.11 hydrogen service level

#### HSL

pressure level in MPa used to characterize the hydrogen service of the dispensing system based on the NWP of the vehicle

Note 1 to entry: See ISO 19880-1:2020, Annex E for application of pressure terminology to hydrogen dispensing systems and vehicles.

### 3.12 maximum allowable working pressure

#### MAWP

maximum pressure permissible in a system at the temperature specified

Note 1 to entry: The maximum allowable working pressure can also be defined as the design pressure, the maximum allowable operating pressure, the maximum permissible working pressure, or the maximum allowable pressure for the rating of pressure vessels and equipment manufactured in accordance with national pressure vessel codes.

Note 2 to entry: See ISO 19880-1:2020, Annex E for discussion of pressure terminology and its application to dispensing systems and fuelling stations in general. Pressures are understood to be gauge unless otherwise specifically indicated in this document.

### 3.13 maximum developed pressure

#### MDP

highest pressure achieved during infrequent, short-term excursions above MAWP during fault management

Note 1 to entry: See ISO 19880-1:2020, Annex E for a discussion of pressure terminology and its application to dispensing systems and fuelling stations in general. Pressures are understood to be gauge unless otherwise specifically indicated in this document.

### 3.14 maximum fuelling pressure

#### MFP

maximum pressure expected during a normal (fault-free) vehicle fuelling

Note 1 to entry: Per GTR#13, the maximum fuelling pressure is 125 % NWP for road vehicles.

Note 2 to entry: See ISO 19880-1:2020, Annex E for a discussion of pressure terminology and its application to dispensing systems and fuelling stations in general. Pressures are understood to be gauge unless otherwise specifically indicated in this document.

**3.15**  
**maximum operating pressure**  
**MOP**

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

Note 1 to entry: In the case of the *dispensing system* (3.7), the MOP is equivalent to the *maximum fuelling pressure* (3.14) of the vehicle.

Note 2 to entry: See ISO 19880-1:2020, Annex E for discussion of pressure terminology and its application to dispensing systems and fuelling stations in general. Pressures are understood to be gauge unless otherwise specifically indicated in this document.

**3.16**  
**nominal working pressure**  
**NWP**

pressure within a hydrogen storage container(s) in the vehicle fuel system at 100 % SOC at a gas temperature of 15 °C

Note 1 to entry: For road vehicles, this is typically 35 MPa or 70 MPa.

Note 2 to entry: See ISO 19880-1:2020, Annex E for discussion of pressure terminology and the correspondence between vehicle terminology and dispensing systems. Pressures are understood to be gauge unless otherwise specifically indicated in this document.

Note 3 to entry: Also known as “settled pressure” in ISO 10286.

[SOURCE: ISO 19880-1:2020, 3.51, modified to replace “CHSS” for road vehicles with the more general term “hydrogen storage container(s) in the *vehicle fuel system*”. ]

**3.17**  
**non-comm fuelling**

fuelling that is conducted without communications between the vehicle and the dispensing control system

Note 1 to entry: *Non-comm fuelling* is equivalent to a *UCDC* (3.25) of 0.

**3.18**  
**non-public fuelling station**

fuelling station that does not sell or dispense gaseous hydrogen to the general public

EXAMPLE Private or municipal vehicle fleet operation

[SOURCE: ISO 19880-1:2020, 3.52]

**3.19**  
**physics-based model**

representation of the governing laws of nature such as the equation of state for compressed hydrogen gas and the conservation of mass, momentum and energy as applied in thermodynamics, fluid mechanics and heat and mass transfer equations

Note 1 to entry: Physics-based models can be empirically adjusted to improve accuracy within the range of interest.

**3.20**  
**public fuelling station**

fuelling station that sells gaseous hydrogen to the public

[SOURCE: ISO 19880-1:2020, 3.62, modified - the text “general public” has been changed to “public”]

**3.21**  
**risk assessment**

determination of quantitative or qualitative value of risk related to a specific situation and a recognised threat

Note 1 to entry: See ISO 19880-1 for a discussion of the risk assessment process as well as examples of threats and hazards.

Note 2 to entry: A recognized threat is also referred to as a hazard.

[SOURCE: ISO 19880-1:2020, 3.66, modified - text from the definition moved to Note 2 to entry.]

### 3.22

#### **safety function**

function to be implemented by a safety-instrumented system that is intended to achieve or maintain a safe state for the process with respect to a specific hazardous situation

Note 1 to entry: See ISO 19880-1 for a discussion of safety-instrumented systems and their application to dispensing systems and fuelling stations in general.

[SOURCE: ISO 19880-1:2020, 3.71, modified - Note 1 to entry has been replaced.]

### 3.23

#### **standards development organization**

##### **SDO**

industry- or sector-based standards organization that develops and publishes industry specific standards

Note 1 to entry: In some cases, international industry-based SDOs can have direct liaisons with international standards organizations. SDOs are differentiated from standards setting organizations (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 recognized 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]

### 3.24

#### **state of charge**

##### **SOC**

density (or mass) ratio of compressed hydrogen in the vehicle fuel system between the actual condition and the capacity at NWP when the system is equilibrated at 15 °C

Note 1 to entry: SOC is typically expressed as a percentage. See ISO 19880-1:2020, 3.78 for details related to the calculation process.

[SOURCE: ISO 19880-1:2020, 3.78, modified - replaced *CHSS* (3.2) for road vehicles with the more general term “*vehicle fuel system*” (3.27) and Notes 1 to 4 to entry have been removed.]

### 3.25

#### **use classification of data communicated**

##### **UCDC**

numerical ranking of data communicated between the vehicle and the dispensing systems based on its use within the fuelling protocol as supported by risk assessment for the following four levels of UCDC:

- 0) No *data* (3.5) is communicated (e.g., *non-comm fuelling* (3.17));
- 1) The *data* communicated is not used for safety functions but is available for *data* collection and, if countermeasures are provided to mitigate risks (if any) resulting from faults, can also be used to improve the performance of the basic process control for fuelling protocol;
- 2) Communicated *static data* (3.5.2) is used for safety functions (in addition to the allowed usages for static and *dynamic data* (3.5.1) defined for UCDC of 1);
- 3) *Static* and *dynamic data* is used for dynamic control within the protocol or safety functions.

**3.26  
validation**

assurance that a product, service, or system meets the needs of the customer and other identified stakeholders

Note 1 to entry: See the definition of *verification* (3.28).

**3.27  
vehicle fuel system**

assembly of components used to store or supply hydrogen fuel to a fuel cell (FC) or internal combustion engine (ICE).

Note 1 to entry: For road vehicles, the vehicle fuel system includes all CHSSs (3.2) on the vehicle where the CHSSs are interconnected in parallel.

[SOURCE: ECE/TRANS/180/Add.13/Amend.1 UN GTR No. 13, UN Global Technical Regulation on Hydrogen and Fuel Cell Vehicles: 2023, 3.54]

**3.28  
verification**

evaluation using subscale and full-scale tests, analyses, or a combination of tests and analyses that demonstrate a product, service, or system complies with regulations, requirements, specifications, or imposed conditions.

Note 1 to entry: *Verification* is typically conducted as part of the development process whereas *validation* (3.26) is typically conducted after the completion of development to confirm acceptability to customers and stakeholders.

**4 Abbreviations and symbols**

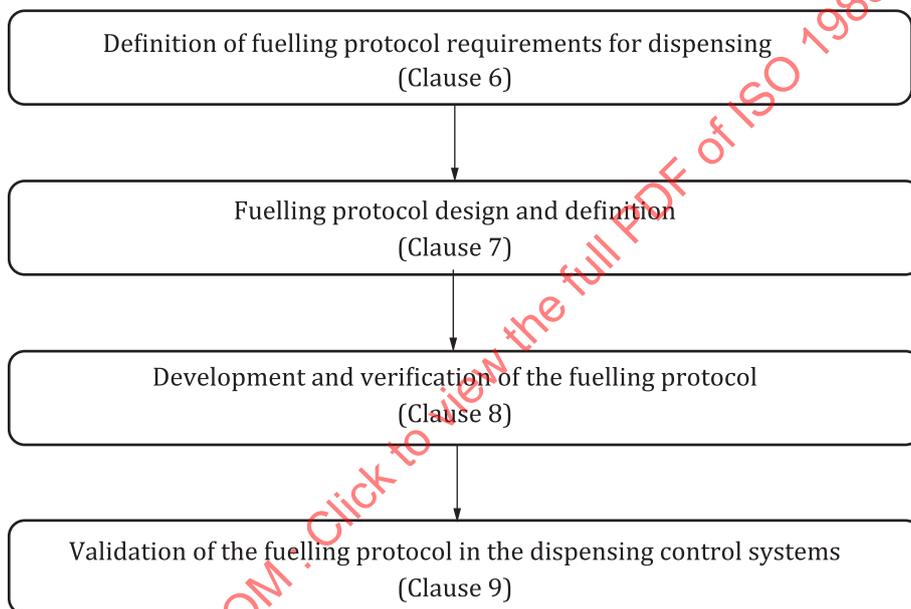
BPCS	Basic process control system
CHSS	Compressed hydrogen storage system
FCEV	Fuel cell electric vehicle
GTR	Global technical regulation
HSL	Hydrogen service level
H35	Indication for 35 MPa NWP hydrogen fuelling
H70	Indication for 70 MPa NWP hydrogen fuelling
L/D	Length-to-Diameter ratio of a container
MAWP	Maximum allowable working pressure
MDP	Maximum developed pressure
MFP	Maximum fuelling pressure
MOP	Maximum operating pressure
NWP	Nominal working pressure
SDO	Standards development organization
SAE	Society of Automotive Engineers International
SOC	State of charge

T/F	True or False as possible values for logical variables
TPRD	Temperature-activated pressure relief device
UCDC	Use Classification of Communicated Data

## 5 General description of the fuelling protocol design and development process

This document is intended to coordinate with the ISO 19880 series with regard to road vehicles and, at the same time, address a more general need with the regard to fuelling a far broader range of vehicles as defined in [Clause 1](#).

Requirements for the design and development of fuelling protocols are organized into four process areas defined in [Clauses 6](#) through [9](#) (see [Figure 1](#)). The requirements are based on learnings from previous fuelling protocol development activities and are intended to provide an efficient and orderly methodology for verification of fuelling protocols and validation of implementation and function in dispensing control systems for fuelling hydrogen vehicles.



**Figure 1 — Process areas with fuelling protocol-specific requirements**

The intent is to integrate the specific requirements of each of the four process areas into the appropriate steps of the designer's and developer's existing processes. The specific requirements for the four process areas are defined in [Clauses 6](#) through [9](#). See also [Annex B](#) for additional information and guidance relative to addressing [Clauses 6](#) through [9](#), respectively.

The requirements defined in each of the key process areas must be documented (and updated if changes occur). This documentation is essential to understand the requirements and limits for proper use of the fuelling protocol and to provide the technical information necessary for implementing the fuelling protocol into the dispensing control system including countermeasures for potential process deviations and faults.

This document is intended to apply to modifications to existing fuelling protocols (which have already been evaluated) as well as new fuelling protocols for compressed hydrogen dispensing systems.

In addition to the requirements for fuelling protocol definition and development in the main body of this document, [Annex A](#) provides requirements and information specific to fuelling protocols for road vehicles at public fuelling stations based on ISO 19880-1. Fuelling protocols for road vehicles at public fuelling stations shall be in accordance with [A.6](#) through [A.9](#).

While [Annex A](#) addresses a specific segment of the industry, designers/developers of fuelling protocols for other hydrogen vehicles can find that [Annex A](#) provides useful examples of how to apply the general process to other hydrogen vehicle applications.

## 6 Definition of fuelling protocol requirements for dispensing

### 6.1 Definition of basic requirements for the fuelling protocol

A clear understanding of the capabilities and limitations of the fuel systems in the vehicle and the dispensing system is necessary before the fuelling protocol can be defined and developed. To ensure that hydrogen dispensing is conducted safely, the basic requirements for the fuelling protocol defined below in this subclause and the information defining the fuelling envelope in [6.2](#) shall be consistent with the capabilities of the vehicle fuel system.

Since, as described in [B.2](#), the objective of the fuelling protocol is to fill the vehicle fuel system to the maximum state-of-charge (SOC) without exceeding temperature and pressure limits of the vehicle fuel system during normal (i.e., fault-free) fuelling, the basic requirements for the fuelling protocol are as follows:

- maximum state-of-charge (SOC),
- maximum allowable container temperature, and

NOTE See [6.2.2](#) relative internal temperature monitoring of containers. See also [B.3](#) and [B.4](#) for general guidance and [A.5.1](#) for information related to gas temperature sensors in containers for road service.

- maximum pressure.

Applicable vehicle regulatory requirements and standards can define parameters for the basic requirements listed above. If applicable regulations and standards are not available or any of the parameters listed above are not defined in the regulations or standards, then these parameters shall be determined as part of [6.2.2](#).

### 6.2 Definition of the fuelling envelope

#### 6.2.1 Fuelling requirements based on vehicle regulations and standards

Regulatory requirements and standards can provide information related to expected values and ranges of vehicle operating characteristics as well as minimum capabilities for vehicle fuel systems. The following information shall be defined when applicable to the targeted fuelling application (i.e. parameters can be found in applicable regulations and standards):

- ambient temperature limits of the hydrogen vehicle and corresponding temperature limits surrounding the container(s) in the vehicle to be fuelled,
- allowable minimum and maximum temperatures of fuel being dispensed,
- minimum allowable temperature of container materials,

NOTE See [6.2.2](#) relative internal temperature monitoring of containers. See also [B.3](#) and [B.4](#) for guidance, and [A.5.1](#) for information related to gas temperature sensors in containers for road service.

- minimum and maximum allowable temperature of piping systems including devices (e.g., control valves, check valves, and TPRDs) that close to isolate the vehicle fuel system and prevent leakage,
- the minimum and maximum allowable fuelling rate of the vehicle expressed, for example, as either mass flow rate of fuel being dispensed or pressurization rate (or both),
- minimum allowable pressure for fuelling to be initiated,
- additional vehicle requirements, if any, for actions taken during the vehicle fuelling that need to be addressed in the design of the protocol or as protective measures by the dispensing system,

NOTE For example, the maximum allowable number of flow pauses (for integrity checks, for example) based on cycle life fatigue of check valves.

- maximum allowable working pressure (of hydrogen storage systems) or maximum developed pressure expected during fault management.

Additional items shall be added when necessary.

The vehicle design and operating characteristics defined above shall be used to define requirements for the fuelling protocol that, when combined with requirements in [6.2.2](#) and [6.2.3](#), will form the fuelling envelope based on representative ranges of design and operating characteristics of vehicles to be fuelled at the targeted dispensing systems. See [B.2](#) for guidance.

If applicable regulations and standards are not available or if any of the requirements are not defined in the regulations or standards, then these parameters shall be determined as part of [6.2.2](#).

### 6.2.2 Additional information for vehicle requirements when regulatory requirements and standards are not available

As discussed in [B.2](#), the information defined from vehicle regulations and standards in [6.2.1](#) is not normally sufficient to define all the necessary requirements related to the vehicle, and market surveys of the industry segment to be served including discussions with manufacturers and stakeholders are often necessary to compile information about hydrogen vehicles to be fuelled.

The following information shall be defined at worst-case conditions, when applicable to the targeted fuelling application, based on market surveys:

- number, capacity, type(s), dimensions, and other parameters describing containers in the vehicle fuel system,
- heat transfer, thermal characteristics, and other parameters affecting thermal response of the containers during the fuelling process (such as inlet flow dynamics that can affect gas mixing and possibly cause thermal stratification),
- location, response time, and measurement tolerance of temperature sensor(s) for monitoring the internal temperature of containers and the associated temperature levels and allowable durations as specified by the manufacturer for protection of the container against damage,

NOTE See [B.2](#), [B.3](#), and [B.4](#) for guidance, and [A.5.1](#) for information related to gas temperature sensors in containers for road service.

- pressure drop characteristics between the fuelling interface on the vehicle and the storage containers during the dispensing of hydrogen,
- location of pressure sensors and measurement tolerances,
- heat transfer and thermal characteristics of vehicle fuelling line(s) and all associated components from the fuelling interface (receptacle) that affect the temperature level and thermal response of the hydrogen delivered to containers during dispensing,
- additional vehicle requirements, if any, for actions taken during the vehicle fuelling that need to be addressed in the design of the protocol or as protective measures by the dispensing system,
- initial temperature range of the container(s) and contents as a function of ambient temperature and prior vehicle operation including, if credible, the possibility that the initial temperature of contents in container(s) is higher than expected due to the vehicle undergoing a prior partial fill without opportunity for the contents to cool down to the expected operating range, and
- hot and cold soak initial conditions of container(s) based on stabilization at the minimum and maximum ambient temperatures (identified above) and definition of a possible intermediate soak condition based on stabilization of the container at a temperature between the minimum and maximum ambient temperatures when, for example, the vehicle is parked or stored in an environmentally-controlled space or enclosure such as a heated or cooled garage or enclosure.

Additional information shall be added when necessary.

The vehicle design and operating characteristics defined above shall be used to define requirements for the fuelling protocol that, when combined with requirements in [6.2.1](#) and [6.2.3](#), will form the fuelling envelope based on representative ranges of design and operating characteristics of vehicles to be fuelled at the targeted dispensing systems. See [B.2](#) for guidance.

### 6.2.3 Requirements based on dispenser design and operating characteristics

As discussed in [B.2](#), the capabilities and limitations of the dispensing systems that will employ the fuelling protocol also need to be considered.

The following information shall be defined at worst-case conditions, when applicable to the targeted fuelling application, based on the design and operating conditions of the dispensing systems:

- ambient temperature range for dispensing,
- fuel supply capability (i.e., pressure and flow) and capacity (total mass that can be delivered during fuelling) based on fuelling station compression and storage,
- temperature of dispensed fuel based on precooling temperatures and capability (if precooling used) or ambient conditions,
- initial conditions (i.e., temperature, pressure, flow) when the dispensing of fuel is commenced,
- heat transfer and thermal characteristics of station fuel dispensing components (i.e., fuelling lines, breakaway fittings, hose and nozzle) that affect the temperature level and thermal response of the hydrogen delivered during dispensing to the vehicle,
- location and measurement tolerances of pressure and temperature sensors,
- pressure drop of equipment and piping within the dispensing systems, and
- number and pressure level of dispenser integrity checks during the dispensing process based on vehicle cycle life capability (defined in [6.2.1](#)) and regulatory requirements, if any.

Additional parameters shall be added when deemed necessary by risk assessment.

The dispensing system design and operating characteristics defined above shall be used to define requirements for the fuelling protocol that, when combined with requirements in [6.2.1](#) and [6.2.2](#), will form the fuelling envelope based on representative ranges of design and operating characteristics of vehicles to be fuelled at the targeted dispensing system(s). See [B.2](#) for guidance.

### 6.3 Dispenser application considerations

Knowledge of the proposed application for the dispenser can establish performance goals for the systems (required to meet customer or stakeholder expectations) as well as an understanding of the physical and management protections available at the targeted site(s).

The following information shall be defined when applicable to the targeted fuelling application:

- definition of vehicles to be fuelled and fuelling time goals,
- performance during high load (i.e., usage) conditions of the fuelling stations such as, for example, the minimum time between refuelling of two consecutive vehicles, the amount of hydrogen available for dispensing, or the rate of hydrogen dispensing as a function of pressure level of hydrogen storage at the fuelling station and compression capability,
- allowable change in performance of the dispensing system as a function of changes in ambient conditions,
- ability to reach but not exceed 100 % SOC (or at least a satisfactory level),

- administrative actions and restrictions of use including, for example, possible supervision of fuelling, limitations of hours of operation, lock-outs, fencing, and security codes, and
- public or non-public fuelling station(s).

Additional parameters shall be added when necessary to define and verify the fuelling protocol.

Also, any requirements in [6.2](#) that are affected by the information listed above shall be updated to be consistent with the targeted application. See [B.2](#) for guidance.

## 7 Fuelling protocol design and definition

### 7.1 Fuelling protocol design

A fuelling protocol shall be designed that satisfactorily meets the requirements for dispensing based on basic requirements in [6.1](#) and the fuelling envelope formed by combining [6.2.1](#), [6.2.2](#), and [6.2.3](#).

The fuelling protocol can be original or a modification to an existing fuelling protocol as determined by the designer. In either case, the defined protocol shall be subject to risk assessment in [7.3](#) and subsequent verification and validation as defined in [Clauses 8](#) and [9](#), respectively.

The designer shall determine whether the fuelling protocol will include communications between the vehicle and dispensing control system. See [B.3](#) for guidance. If communications are used, the communications shall meet requirements in [7.2](#). The assigned UCDC level in [7.2](#) shall be subjected to a risk assessment as described in [7.3](#), and the designer shall verify that countermeasures are provided when necessary to mitigate increased risks when using UCDC 0 or 1.

The designer shall also determine (as supported by risk assessment in [7.3](#)) to either terminate the fuelling process if the communication fails or continue the fuelling without further communications (e.g., in UCDC of 0) using a backup protocol. The choice of backup protocol can be different depending on which phase of the fuelling process the communication is interrupted. Furthermore, if the communication is re-established, the designer can elect to return from the backup protocol to the original fuelling protocol when supported by risk assessment. The backup non-comm fuelling protocol can be based on a published non-comm fuelling protocol and can limit the amount of fuel dispensed to lower risk and thereby simplify verification as defined in [8.1](#).

The fuelling protocol design and the backup(s) as defined above shall be documented. The designer has flexibility as to the form of the fuelling protocol documentation as long as the definition of the protocol is clear and ultimately can be translated to hardware and software of the dispensing (and possibly vehicle) control system(s).

### 7.2 Communications between the vehicle and dispensing system

If communications are used, the required UCDC level shall be determined based on the use of the communicated data by the fuelling protocol as defined in [7.1](#). Only data communicated between the vehicle and dispensing systems are subject to limitations on use of data as defined by UCDC. See [3.25](#) for definition of UCDC levels and [B.3](#) for guidance.

Data required to execute the fuelling protocol shall be defined along with UCDC level. The selected UCDC level and communications system shall be supported by the risk assessment in [7.3](#).

Designers and developers of the fuelling protocol shall adopt designs consistent with requirements of the selected communication system for pre-fuelling communications between the vehicle-to-dispenser control systems, conducting the fuelling process, and post-fuelling before closing the communications as supported by risk assessment for the targeted application.

NOTE ISO 19885-2 is under development to address communication requirements.

The following items shall be addressed for pre-fuelling, and, when appropriate based on risk assessment of the targeted application with consideration of [6.3](#), the information required to support each item shall be defined:

- Definition of the pairing process for the vehicle and dispensers;
- Method to identify the vehicle and/or vehicle fuel system to be fuelled;
- Approach to secure communications;
- Requirements to authorize the fuelling (e.g., on certifications and approvals, accident, inspection, and maintenance reports supporting current condition of the vehicle fuel system);
- Readiness to initiate fuelling (e.g., temperature and pressure of container(s) in the vehicle fuel system); and
- Process to negotiate fuelling protocols and their backups, if any, for the fuelling process including safety-critical implications for protocols requiring UCDC level of 2 or 3. See also [B.3](#) for guidance.

Additional parameters shall be added when necessary.

If the pre-fuelling communication process is not successfully completed, then, when possible, remedial measures shall be considered to allow the vehicle to be fuelled. If an acceptable alternative cannot be defined, then the communication shall be closed without fuelling the vehicle.

The following items shall be addressed for post-fuelling before closing communications, and, when appropriate, the information required to support each item shall be defined:

- Method to close communications;
- Reporting and logging of final pressure and temperature(s) of the container(s) and estimated SOC at the end of the fuelling process;
- Reporting and logging of fault conditions, if any, occurring during the fuelling process and countermeasures.

Additional parameters shall be added when necessary.

Based on the above considerations the designer and developer may select an existing fuelling communication approach/protocol or defer the decision to implementors of the fuelling protocol in dispensing control systems.

The information defined above shall be documented and included as part of the design definition of the fuelling protocol.

### 7.3 Risk assessment and fault management

The designer of the protocol shall perform a preliminary risk assessment to identify hazards and define countermeasures to reduce risk to acceptable levels. The hazards shall not be limited to the possibility of exceeding the safe fuelling limits but shall also include other potential hazards commonly expected in the targeted application such as leaks, which could lead to countermeasures implemented in the fuelling protocol as well as the identification of safety functions in the dispensing system. See [B.3](#) and ISO 19880-1 for guidance relative to the conduct of the risk assessment and examples of hazards to be addressed.

If the fuelling protocol is a modification of an existing protocol, then the modification shall be considered as part of the risk assessment (and subsequent verification except as noted in [8.1](#)).

In some cases, process deviations and faults can be managed by incorporating countermeasures into the fuelling protocol to allow the fuelling process to continue with acceptable risk. Potential mitigations identified in [6.3](#) can also be considered when appropriate. However, in other cases, the process will need to be terminated and the hydrogen supplied to the dispensing system isolated.

If data is communicated between the vehicle and the dispensing system, the risk assessment shall consider the integrity of the data. In addition to the communication system itself, the possibility of measurement

errors, process deviations, and faults within the system that generates the data shall be considered as part of the risk assessment. See [B.3](#) and [B.4](#) for examples of issues commonly experienced during the fuelling of containers on vehicles. Acceptable countermeasures shall be defined to mitigate potential issues.

Data measured directly by the dispenser shall also be addressed as part of the risk assessment (even though this data is not subject to limitations based on UCDC classification). The possible occurrence of measurement inaccuracies and faults shall be considered, and acceptable countermeasures shall be defined to mitigate potential issues.

If a backup fuelling protocol is used as part of the fault management strategy, then the backup fuelling protocol is also subject to risk assessment (and subsequent verification except as noted in [8.1](#)).

The risk assessment shall be documented to clearly define the required actions and constructs as well as any fault management countermeasures that are necessary for proper implementation of the protocol in dispensing systems. All identified necessary safety functions shall be documented and transferred to the dispensing and possibly the vehicle system developers for implementation.

## 8 Development and verification of the fuelling protocol

### 8.1 Verification of the fuelling protocol

As part of the development process, the developer shall verify that the fuelling protocol (defined in [Clause 7](#) including any countermeasures that are used to manage process deviations or potential faults) meets requirements (defined in [Clause 6](#)) over the entire fuelling envelope such that the dispensing of hydrogen to vehicles can be conducted in a safe manner.

Verification of the protocol shall be accomplished through a combination of analyses and tests. If the protocol allows alternative measures or strategies to be employed when a process deviation or fault is detected, then these possibilities shall be explored as part of the overall verification. For example, if the fuelling protocol is designed to function without communications when the communication fails, then the back-up non-comm fuelling protocol shall also be verified except when an existing fuelling protocol that has been previously verified is selected for back-up. Modifications, if any, to the existing protocol shall be verified unless the modifications reduce the amount of fuel dispensed and therefore reduce the pressure level and risk.

Verification testing can be conducted on actual vehicle containers or representative subscale or full-scale test cylinders if the cylinder captures the required physics of the fuelling process. See [B.4](#) for guidance.

Given the likely large number of design cases that need to be addressed, it is anticipated that numerous scenarios will need to be evaluated by validated analytical models. The models can range from simple reduced-order models to detailed models as long as models are sufficiently detailed to capture the required physics, as deemed necessary by risk assessment, for the particular situation being posed by the use of the fuelling protocol. Models can be empirically tuned to improve accuracy of predictions for the range of interest during the fuelling process. See [B.4](#) for guidance.

Models shall be validated based on test results or derived from other fully documented more complex models. As a minimum, the models shall satisfactorily match results of verification tests conducted as part of the overall verification activity.

The entire range of the fuelling envelope developed in [6.2](#) shall be addressed to demonstrate that fuelling protocol maintains the vehicle fuel system within the limits defined in [6.1](#). See [A.5.1](#), [B.3](#), and [B.4](#) for additional information and guidance. Worst-case combinations of vehicle fuel system and dispenser design characteristics and limitations shall be evaluated as supported by risk assessment based on the ranges of parameters in the fuelling envelope as defined in [6.2](#). Examples of parameters defined in [6.2](#) that are expected to be evaluated during verification are as follows:

- The total volume of vehicle storage system,
- The number of containers in the vehicle storage system,
- Capacity and type of container(s),

- Container design configuration such as L/D and mixing characteristics of inlet gas in the container during fuelling,
- Precooling capability, if used, of the dispensing system and heat transfer characteristics of dispenser lines that can affect the temperature of gas delivered to the containers in the vehicle fuel system,
- Pressure drop and associated heating of fuel being dispensed to container, and
- Fuelling rate (including the fuelling rate that generates the highest container temperature), expressed as either mass flow rate of fuel being dispensed or pressurization rate.

All design parameters characteristics defined in 6.2.1, 6.2.2 and 6.2.3 shall be considered as supported by risk assessment to define worst-case situations. At a minimum, the worst-case situations shall be evaluated at the initial and ambient conditions defined in Table 1 where the first four cases are based on evaluating the inflection points on the boundary of the fuelling envelope illustrated in Figure B.1 and the latter three cases address situations within the interior of the fuelling envelope.

**Table 1 — Initial and ambient conditions to be verified**

Case number	Initial condition of the container			Ambient temperature
	Pressure	Material temperature <sup>a</sup>	State-of-charge	
<i>Cases based on inflection points along boundary of fuelling envelope:</i>				
1	Minimum <sup>b</sup>	Maximum <sup>e</sup>	Not specified	Maximum <sup>c</sup>
2	Minimum <sup>b</sup>	Minimum <sup>d</sup>	Not specified	Maximum <sup>c</sup>
3	Minimum <sup>b</sup>	Minimum <sup>d</sup>	Not specified	Minimum <sup>b</sup>
4	Minimum <sup>b</sup>	Maximum <sup>f</sup>	Not specified	Minimum <sup>b</sup>
<i>Cases inside the fuelling envelope:</i>				
5	Minimum <sup>b</sup>	20 ± 10 °C	Not specified	20 ± 10 °C
6	Not specified	Minimum ambient <sup>b</sup>	50 % SOC	Minimum <sup>b</sup>
7	Not specified	Maximum ambient <sup>c</sup>	50 % SOC	Maximum <sup>c</sup>
<sup>a</sup> Container soaked (i.e., equilibrated) to the indicated temperature. <sup>b</sup> Minimum value as defined for the fuelling envelope in 6.2. See also B.1. <sup>c</sup> Maximum value as defined for the fuelling envelope in 6.2. See also B.1. <sup>d</sup> Minimum soak temperature of the container material as defined for the fuelling envelope in 6.2. <sup>e</sup> Maximum soak temperature of the container material as defined for the fuelling envelope in 6.2. <sup>f</sup> Maximum temperature of the container material based on greater of intermediate soak as defined for the fuelling envelope in 6.2 or the value per note e.				

If the fuelling protocol uses data that is communicated from the vehicle for conduct of the fuelling process, then supporting information (based on data and analyses) developed by the vehicle or container manufacturer as part of third-party approval and/or regulatory compliance can be considered to supplement or offset (i.e., replace the need for) necessary verification tests or analyses for the fuelling protocol when supported by risk assessment. See B.4 for guidance.

Alternatively, when the data provided for safety functions is deemed sufficient by risk assessment to protect the dispensing and the vehicle fuel systems (including communicated dynamic data used for safety functions at UCDC of 3), then verification of the fuelling protocol shifts to demonstrating acceptable performance over the fuelling envelope without exceeding CHSS container(s) limits as defined in 6.1 such that low-demand/on-demand safety functions are not required to activate during normal (i.e., fault-free) fuellings. At a minimum, Cases 1 and 7 shall be addressed to demonstrate acceptable fills without activating low-demand/on-demand safety functions.

The basis and results of the verifications shall be documented as proof that the fuelling protocol meets requirements in Clause 6. If models are used as part of the verification, then the basis for model validation shall also be documented. Documentation originally defined in Clauses 6 or 7 shall also be updated to reflect any adjustments or clarifications made to complete verification.

## 8.2 Documentation and standardization of the fuelling protocol

After completing the verification of the fuelling protocol, documentation originally defined in [Clauses 6 or 7](#) shall be updated to reflect any adjustments or clarifications needed to complete verification in [8.1](#). As a minimum, the following shall be addressed:

- requirements (and sources) including fuelling targets and limits (from [6.1](#)), the fuelling envelope (from [6.2](#)), and dispenser application considerations (from [6.3](#));
- the design description of the fuelling protocol and backup, if used (from [7.1](#));
- the definition of data required to execute the fuelling protocol, the required UCDC level of communications between the vehicle and the dispensing control systems (from [7.2](#)), and information that needs to be transferred between the vehicle and dispensing control systems as part of pre-fuelling and post-fuelling communications, if used;
- summary of the risk assessment including the required actions as well as any fault management countermeasures that are necessary for proper implementation of the protocol in dispensing systems (from [7.3](#)); and
- a report describing the verification process that was used and presenting the results of analyses and tests from [8.1](#) that supports the compliance to requirements defined in [Clause 6](#) with sufficient detail so that manufacturers (and stakeholders) of dispensing systems, vehicles, vehicle fuel systems and containers can determine if the fuelling protocol is applicable to their systems and can be used with acceptable risk.

Instructions and other information shall also be provided for implementing the fuelling protocol in the dispensing control (and possibly vehicle control) systems and for confirming proper installation in the control systems. Examples of information that shall be defined when applicable are as follows:

- maximum allowable update intervals of data and fuelling protocol calculations;
- software checks to confirm the protocol is fully functional;
- the minimum and maximum required flow versus dispensing pressure required to execute the fuelling protocol so that dispenser flow control valve(s) can be sized and turn-down requirements can be established (when combined with process information from the fuelling station); and
- response rate or time of dispenser flow controls to changes in setting.

Additional information shall be added when necessary.

If the fuelling protocol is to be published by an SDO as a consensus-based standard, then the information required by this subclause shall be included in the published standard or other published report as evidence of compliance to this document.

## 9 Validation of the fuelling protocol in the dispenser control systems

The objective of this clause is to validate that the fuelling protocol can be successfully implemented in a dispensing control system that is representative of targeted applications using documentation defined in [8.2](#). Control systems shall comply with the requirements of IEC 60204-1 (applicable regional standards can exist).

All countermeasures to process deviations and faults including branches in logic and backup fuelling protocols shall be included as part of the implementation of the fuelling protocol in the dispensing control system. If communications between the vehicle and the dispensing system are used, then communications shall also be provided for validation testing. IEC 61508 and IEC 61511 shall be used for the design and testing of safety functions when deemed appropriate by risk assessment. IEC 62061, ISO 13849-1, and ISO 13849-2 shall also be used for additional options to fulfil functional safety requirements when required by risk assessment.

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A validation plan shall be developed to fully test the functionality of the fuelling protocol:

- Items defined in [8.2](#) shall be performed to confirm the installation of the fuelling protocol in the dispensing (and possibly vehicle) control systems.
- The functionality of the dispensing control system shall be validated by conducting fuellings of vehicles and/or representative test systems. All process adjustments which are part of the fuelling protocol as well as protective functions shall be tested to confirm that the fuelling protocol is fully functional and supports necessary countermeasures against process deviations and faults.
- If the fuelling protocol as part of pre-fuelling communications between the vehicle and the dispensing control system negotiates the use of the fuelling protocol and backup(s), then this feature shall be validated to ensure that unauthorized fuellings do not occur.

Tests can be performed, as appropriate, in the factory, test facilities, and/or at fuelling stations.

Documentation developed in [8.2](#) shall be updated to reflect learning from validation activities when appropriate.

The initial validation testing of the fuelling protocol as defined above shall be performed on at least one representative dispensing control system, unless changes are made to the fuelling protocol that necessitate re-validation based on risk assessment.

NOTE 1 The above only addresses validation of the fuelling protocol (and not the dispensing system).

NOTE 2 Validation requirements of dispensing systems are not addressed by this document as they are expected to be conducted as part of the design and development, fabrication and assembly, and installation processes of the manufacturer based on standard industry practices and applicable standards and regulations for the specific application.

In order to continue validation of the fuelling protocol based on operation of dispensers in the field, a mechanism shall be provided for reporting safety-related incidents and near-misses and for taking corrective actions, when required, to update the fuelling protocol and associated documentation defined in [8.2](#).

## Annex A (Normative)

# Development requirements for fuelling protocols of road vehicles

### A.1 Introduction

The purpose of this annex is to define design and development requirements for fuelling protocols for hydrogen and fuel cell road vehicles by providing specific information for compliance with [Clauses 6](#) through [9](#) of this document. [Subclauses A.6](#) through [A.9](#) are normative and in accordance with [Clauses 6](#) through [9](#), respectively. [A.2](#) through [A.5](#) provide information and guidance relative to meeting the normative requirements of this annex.

This annex focuses on the design and development of fuelling protocols for dispensing compressed hydrogen gas to road vehicles compliant with GTR #13 at public fuelling stations. As such, this annex relies on GTR #13 for the key design and operating characteristics of road vehicles and the ISO 19880 series for the design and operating characteristics of dispensing systems at public fuelling stations.

While focus of this annex is the fuelling of road vehicles generally compliant with GTR #13 at public fuelling stations, the annex also addresses possible exceptions when regional regulations allow the fuelling of vehicles that are not necessarily compliant with GTR#13 or when administrative controls are in place such as for private (non-public) fuelling of fleet vehicles where the range of vehicles that need to be addressed is less than the full range of vehicles and fuelling situations addressed in GTR #13.

This annex is applicable to the development of new protocols or the modification of existing protocols for road vehicles in accordance with this document.

### A.2 Rationale for using road vehicle-specific normative references

As noted in [A.1](#), the ISO 19880 series is used as the source of information for the design and development of fuelling protocols for road vehicles and therefore included as a normative reference in [Clause 2](#). This was done as ISO 19880-1 defines requirements for public fuelling stations, ISO 19880-2<sup>1)</sup> defines requirements for dispensers, and other documents in the series define pressure drop and flow characteristics for dispenser components which are likely to affect the information compiled in [A.6.2](#) as well as the selection of test equipment for fuelling protocol validation in [A.9](#).

ISO 17268 is added to [Clause 2](#) as this standard defines fuelling nozzles and receptacles for road vehicles. The standard defines flow capacities and ability to measure pressure drops of nozzles and receptacles expected on dispensers and vehicles.

ISO 26262 and ISO/SAE 21434 were also added as these documents apply to functional safety and cyber security, respectively, for the road vehicle(s) and test equipment for validation of the fuelling protocol.

Finally, GTR #13 is added to the Bibliography as it is normative to only the road vehicle and not the fuelling protocol.

### A.3 Information related to road vehicle-specific terms and definitions

Road vehicle-specific definitions from GTR #13 were added to [Clause 3](#) for the purpose of designing and developing fuelling protocols for road vehicles as defined by this annex.

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1) Under preparation. Stage at the time of publication: ISO/DIS 19880-2:2023

The road vehicle-specific definition of “container” in [3.3](#) was created for GTR #13 to accommodate the use of conformable containers (that consist of bundles of tube arrays for storing hydrogen in irregular and small spaces of vehicles) in addition to storage in compressed gas cylinders. Depending on the type of road vehicles expected to be fuelled at the fuelling station, the possibility of fuelling vehicles with conformable containers needs to be considered when designing and developing the fuelling protocol in [A.6](#) through [A.9](#). See GTR #13 for additional information and guidance.

GTR #13 also defines the compressed hydrogen storage system (CHSS) for road vehicles in [3.2](#) such that only one container can be within the CHSS. The road vehicles therefore typically require more than one CHSS to store the hydrogen needed for the vehicle fuel system of the road vehicle.

## **A.4 Information related to the conduct of the design and development of fuelling protocols for road vehicles**

While the requirements for the design and development of fuelling protocols are organized into four process areas, the intent is not to force designers and developers of fuelling protocols for road vehicles to adopt a new design and development process but rather for developers to integrate the requirements in [Clauses 6](#) through [9](#) and the supplemental information specifically for road vehicles in [A.6](#) through [A.9](#) into their existing developing processes.

## **A.5 Technical guidance relative to [A.6](#) through [A.9](#)**

### **A.5.1 Temperature monitoring of CHSS containers**

Manufacturers of CHSS containers for road vehicles have adopted as standard practice the installation of gas temperature sensors inside the CHSS containers for hydrogen road vehicles even though the sensors are not explicitly required by GTR #13 (but are allowed).

Strictly speaking, the gas temperature sensor does not directly measure the actual gas temperature. While the sensors are physically located in the compressed hydrogen gas space and are heated (or cooled) by convection with surrounding hydrogen gas in the container, the temperature measurement is also influenced by radiation between the sensor and the inner surface of the containers and by conduction through mounts and electrical connections. When the fuelling is complete and the container and the stored hydrogen gas have equilibrated, the temperature measurement is reasonably accurate, but during transient conditions such as the fuelling of containers, the readings represent a combination of the previously explained convective, radiative, and conductive effects. The situation is further complicated by gas temperature variations commonly experienced during the fuelling process depending on the design configuration of the container and the fuelling rates. See [B.2](#), [B.3](#), and [B.4](#) for additional information. Nonetheless, the gas temperature sensors serve as a practical method of monitoring the internal temperature of the container, particularly when the gas temperature sensors have been characterized and verified during verification of container fuellings. See [A.5.3](#) for an example.

Manufacturers are expected to account for protection of container materials as captured in Item b) in [A.6.1](#) and Item a) 3) in [A.6.2](#), for example, as part of establishing the temperature limits (and possibly the allowable durations of excursions) for gas temperature monitoring. Requirements for implementation of container gas temperature are defined in [A.6.2](#) item b) 5). Verification testing as defined in [A.5.3](#) provides an excellent opportunity for verification of the durability of the containers with the limits specified by the manufacturer.

The gas temperature sensors can also be used as part of the determination for average gas temperature and state-of-charge (SOC) of the container.

### A.5.2 Examples of pre-fuelling communications at public fuelling stations

If communications between the vehicle and the dispensing control system are used, then the following information should be considered as part of addressing items defined in 7.2 for pre-fuelling of road vehicles:

- a) Approaches to identify road vehicles at public fuelling stations have not been standardized and are still under consideration. Examples are use of:
  - 1) globally unique identifiers of the digital communications,
  - 2) vehicle manufacturer identification codes and vehicle description codes based on ISO 3779, and
  - 3) manufacturer codes and descriptions of vehicle fuel systems.
- b) Examples of certification and approvals relevant to road vehicles are that:
  - 1) the vehicle is approved or compliant to GTR #13 or, if not GTR #13, to other standards,
  - 2) the vehicle is legally registered,
  - 3) inspections of the vehicle and vehicle fuel system as required by local authorities have been conducted and are up-to-date, and
  - 4) maintenance activities as required by the manufacturer have been completed.
- c) Confirmation that crash sensors on the vehicle, when available, have not activated or, if they have, post-crash inspection of the vehicle fuel system has been conducted and found acceptable for road service.

### A.5.3 Use of manufacturer data for verification of the fuelling protocol

Tests performed by the container and vehicle manufacturers to demonstrate compliance with GTR #13 offer the possibility to supplement or offset (i.e., replace the need for) the verification analysis and test requirements. While the pneumatic test protocol for CHSS containers in GTR #13 defines a minimum rate of pressurization with compressed hydrogen gas for the simulation of fuellings, there is flexibility for the manufacturer to increase the rate of pressurization to a value specified by the manufacturer and thereby provide the opportunity to demonstrate repeated fuelling of CHSS containers at thermally-challenging ambient and initial conditions without apparent damage (based on successfully completing pressure cycling without rupture and then demonstrating acceptable permeation and leakage).

### A.5.4 Guidance for addressing fuelling protocols for various road vehicles

GTR #13 evaluates CHSSs for road service based on vehicles being either less than or equal to 4 536 kg or vehicles being greater than 4 536 kg. While this approach provides a straight-forward method to conduct regulatory approval of the vehicles, it does not provide an accurate understanding of the hydrogen storage capacity of the vehicle fuel systems or the allowable fuelling (or pressurization) rates for the vehicles undergoing fuelling. These parameters are required to define the basic design and operating parameters (such as the capacity of hydrogen storage and/or flow capability of compression equipment in the fuelling station and maximum flow capacity of the dispensing systems) and ultimately the definition of the fuelling protocol.

The fuelling receptacle selected by the manufacturer for the vehicle provides some insight as to the desired flow capacity for the dispensing based on ISO 17268, but this information is not sufficient by itself. For example, the values in A.6.2 b) and c) are based on the fuelling of light-duty vehicles with compressed hydrogen storage volumes between 49,7 and 248,6 L.<sup>[6]</sup> These light-duty vehicles use receptacles with up to 120 g/s flow rate, but, in fact, there are larger vehicles with storage capacities greater than 248,6 L that use receptacles that will couple with these fuelling nozzles. Fuelling a vehicle with a larger-than-expected hydrogen storage capacity will reduce the pressurization rate and thereby increase the time required to fill the vehicle and possibly cause unnecessary trip of the dispenser control system due to lower-than-expected pressurization rate. Conversely, some vehicles with hydrogen storage capacities less than expected for heavy-duty vehicles could cause controllability issues of the dispensing control systems at low fuel flows including possibly excess cycling of check valves in fuel lines of the dispensing system or the vehicle. Therefore, designers of fuelling protocols shall, in accordance with A.6.3, address this issue by determining

the vehicles (or categories of vehicles) to be fuelled and fuelling time goals at the targeted application and by then confirming that the vehicle requirements in [A.6.2](#) items a) and b) and the dispensing characteristics in [A.6.2](#) item c) are consistent with fuelling the vehicles targeted for the application.

The use of communication between the vehicle and the dispensing system can help resolve some of the variables encountered when fuelling vehicles cited above, but any decisions made as part of this process are subject to risk assessment in [A.7](#) to ensure that appropriate control actions of the fuelling protocol and countermeasures of the dispensing system are in place for the targeted applications. See [6.3](#), [7](#), and [B.3](#).

## A.6 Definition of fuelling protocol requirements for dispensing fuel to road vehicles

### A.6.1 Basic considerations and requirements for the fuelling protocol

Requirements and operating conditions/limits for hydrogen and fuel cell road vehicles are defined in GTR #13. These requirements and operating conditions/limits provide the basis for the definition and development of fuelling protocols for a broad range of road vehicles such as in public fuelling stations.

Basic considerations and requirements when defining the fuelling protocol are listed below.

- a) Special circumstances can allow adjustment of the requirements and of operating conditions and limits defined in the GTR #13. To ensure that hydrogen dispensing is conducted safely, use of any exceptions shall be based on risk assessment and ISO 19881. Examples of such circumstances are when:
- communications between the vehicle and the dispensing control systems have adequate integrity (UCDC of 2 or 3) and both parties have agreed to use a fuelling protocol involving adjustments to safety functions and limits during pre-fuelling communications as defined in [7.2](#),
  - administrative controls or technical countermeasures are in place to prevent the fuelling of vehicles that do not meet the requirements of the protocol such as for the fuelling of a “captive” fleet of vehicles at a private (non-public) fuelling station, or
  - regional regulations allow the fuelling of vehicles that are not necessarily compliant with GTR #13.

Flexibility for such adjustments is indicated within applicable subclauses of [A.6.1](#) item b), [A.6.2](#), and [A.6.3](#) in accordance with [6.1](#), [6.2](#), [6.3](#), respectively.

- b) The following information shall be used to define basic requirements for fuelling protocols in compliance with [6.1](#):
- 1) The CHSS shall be filled to a maximum state-of-charge of 100 % based on the density at the nominal working pressure (NWP) of the vehicle at 15 °C.
  - 2) The maximum temperature of the container pressure-bearing material and the internal liner, if any, shall be 85 °C or less during fuelling (regardless of container type).

EXCEPTION: The temperature limit may be changed when supported by the vehicle manufacturer and one of the following conditions is met:

- Monitoring the temperature within the container at a UCDC level of 2 or 3 allows the temperature limit to be increased up to the maximum temperature specified by the container manufacturer in [A.6.2](#) item b) 5) when supported by verification testing and risk assessment. See [A.5.1](#) and [A.5.3](#) for guidance.
  - Administrative controls or regional regulations allow higher temperature limits to be used by “captive” fleets that can limit the range of the container types and designs of vehicles to be fuelled (when supported by risk assessment).
- 3) The fuelling protocol shall limit the hydrogen pressure dispensed to no more than 125 % of the HSL. This pressure limit may be lowered in regions where local regulations allow vehicles or dispenser equipment with lower pressure capability. The pressure may also be lowered when supported by risk assessment.

## A.6.2 Definition of the fuelling envelope for road vehicles

The information used to develop the requirements for fuelling envelope shall be based on the designs and operating characteristics of the road vehicles to be fuelled and the dispensing system targeted to conduct the fuelling. See [A.5.4](#) for guidance.

The information listed within in items a, b and c below shall be used to define requirements for the fuelling protocol in accordance with [6.2.1](#), [6.2.2](#), and [6.2.3](#), respectively.

- a) The following information based on GTR #13 shall be used to comply with [6.2.1](#) for road vehicles:
- 1) The ambient temperature range for vehicle operation and fuelling is between -40 °C and +50 °C.
  - 2) Dispensing fuel temperature at the vehicle shall be greater than -40 °C.
  - 3) The minimum allowable temperature of container material is -40 °C. See [A.6.2](#) item b) 5) relative to gas temperature monitoring within the CHSS container(s) and [A.5.1](#) for guidance.
  - 4) The minimum and maximum temperature of piping systems including devices (e.g., control valves, check valves, and TPRDs) that close to isolate the vehicle fuel system and prevent leakage is - 40 °C and + 85 °C, respectively, during normal operation.
  - 5) The minimum allowable pressure to initiate the fuelling process is 0,5 MPa.
  - 6) Fault management shall limit the pressure to 150 % of the HSL.

NOTE This pressure is the worst-case MDP based on a relief valve set to protect the dispenser system at its MAWP of 138 % HSL. Additional layers of protection within the dispensing control system are recommended. See ISO 19880-1.

- b) While GTR #13 provided the above requirements for hydrogen road vehicles, additional information related to the vehicles to be fuelled is necessary. The following shall be used to comply with [6.2.2](#):
- 1) The maximum allowable dispenser flow rate (excluding momentary excursions during the initial connection sequence of the dispenser fuelling assembly to the vehicle prior to the start of fuelling) shall be based on the worst-case coupling of a vehicle receptacle as defined in ISO 17268 to the dispenser nozzle.

### EXCEPTIONS:

- The maximum allowable dispenser flow rate is communicated from the vehicle, and the communicated value considers maximum allowable pressurization rate of the CHSS(s) as well as the pressure drop of the nozzle/receptacle coupling.
- Administrative controls justify use of higher dispenser flow rates with acceptable risk for the targeted application.

In addition to ISO 17268, nozzle/receptacle standards such as SAE J2600 should also be checked for worst-case couplings when available in the region of use.

NOTE The above requirement supports setting the maximum allowable dispenser flow rate for non-comm fuellings of light-duty vehicles to no higher than 60 g/s unless administrative controls justify use of higher dispenser flow rates with acceptable risk for the targeted application. See [A.5.4](#) for guidance.

- 2) The type of containers in the vehicle CHSSs is not limited, and any vehicle can have more than one type of container.

EXCEPTION: Administrative controls are in place to address the fuelling of “captive” fleet vehicles with specific types of containers at a private (non-public) fuelling station.

- 3) The pressure drop through the dispenser nozzle when coupled to the vehicle receptacle shall be determined based on the worst-case combination of nozzles (that are specified for use with the fuelling protocol) and mating vehicle receptacles for the targeted fuelling application. The

pressure drop of interconnecting piping system between the receptacle on the vehicle and the CHSS container(s) shall also be included.

NOTE For example, SAE J2601 assumes the total pressure drop does not exceed 20 MPa from the nozzle/receptacle interface at a mass flow 1,5 times the average mass flow required to fuel the vehicle fuel system in 3 minutes for F60 nozzle/receptacle combinations when the CHSS pressure is 10 MPa and fuel delivery temperature is -15 °C.

- 4) Heat transfer and thermal characteristics of vehicle fuelling line(s) from the fuelling interface (at the receptacle) shall be estimated such that the temperature level and thermal response of the hydrogen delivered to the CHSS container(s) during dispensing can be determined. The fuelling lines and components shall be assumed to be initially heat soaked to worst-case temperature when performing this determination. See SAE J2601 for guidance and examples.
- 5) Container manufacturers have adopted the installation of gas temperature sensors in CHSS containers in order to monitor the internal temperature of the container. See [A.5.1](#) for guidance.

When gas temperature sensors are installed, the temperature levels specified by the manufacturer shall not be exceeded to protect the container materials.

If the specified temperature limit is above 85 °C, then the temperature level for thermal protection shall be limited to 85 °C unless a higher temperature level is allowed (by exception) in [A.6.1](#) item b) 2).

- 6) The initial temperature of CHSS container materials for fuelling can vary by  $\pm 15$  °C around ambient temperature due to daily changes in temperature, solar heating of containers inside the vehicle, and/or cooling of the container during vehicle operation.
  - This variation is clipped (i.e., limited) on the extreme low and high temperatures in [A.6.2](#) item a) 1) above to the value of the limits.

Top-offs following recent fuellings of the vehicle can result in the initial temperature of the CHSS container range being higher than +15 °C above ambient if risk assessment indicates that this situation needs to be addressed.

Also, storage of the vehicle in a heated garage can cause the initial temperature of the container materials to be limited to +15 °C for ambient temperatures below +15 °C.

- 7) The number of CHSS containers in light-duty vehicles can vary from one to six. See [A.5.4](#) and SAE J2601 for guidance.

The number and size of CHSS containers for heavy-duty vehicles have not been fully established yet but will likely over-lap the light-duty range and extend to higher values.
- 8) The total capacity of CHSSs in vehicle fuel system of light-duty vehicles is expected to range from 1,2 to 6,0 kg of hydrogen for 35 MPa (NWP) storage systems and from 2,0 to 10 kg of hydrogen for 70 MPa (NWP) storage systems.<sup>[6]</sup> See [A.5.4](#) for guidance.

The expected capacity of CHSSs in vehicle fuel system of heavy-duty vehicles will be larger than the range for light-duty vehicles but has not yet been defined. See SAE J2601-5 for guidance.

- c) Design and operating characteristics of the targeted dispensing system also need to be considered when establishing requirements for the fuelling protocol. The following dispenser design and operating characteristics shall be used to meet [6.2.3](#) for fuelling road vehicles:
  - 1) The ambient temperature range for dispensing shall be within the capability of the vehicle per [A.6.2](#) item a) 1) above but can be narrower in certain regions or applications.
  - 2) Dispensing systems shall not fuel a vehicle which has a pressure lower than 0,5 MPa or greater than the HSL (i.e., 35 MPa or 70 MPa) prior to initiating fuelling.

- 3) Prior to initiating the fuelling of the vehicle, a pressure integrity check shall be conducted. As a consequence of this check, a quantity of hydrogen may be transferred to the vehicle prior to the start of fuelling.
  - The hydrogen mass allowed to be transferred to a light-duty vehicle during this check shall be no more than 200 g.
  - The allowable amount of hydrogen to be transferred during this check for heavy-duty vehicles is likely to be greater than 200 g (when defined).
- 4) Additional integrity checks (beyond the initial integrity check in [A.6.2](#) item c) 3) may be conducted during the fuelling process, but a maximum of 10 pauses is allowed to prevent “chatter” and excessive wear of check valves in the dispensing and vehicle fuel systems.
  - For light duty, a pause occurs when the flow rate drops below 0,6 g/s.
  - The flow rate at which a pause occurs for heavy-duty has not been defined yet. See SAE J2601-5 for guidance.
- 5) Dispenser can precool the hydrogen before dispensing to decrease the dispensing time and the maximum temperature in the container, but the temperature of hydrogen shall not be less than -40 °C.
- 6) The pressure drop between the dispenser pressure measurement location and the vehicle fuelling interface (i.e., the receptacle) shall be estimated. See SAE J2601 for guidance and examples. See also ISO 19880-3 and ISO 19880-5 for information related to breakaways (and valves) and dispenser hose assemblies, respectively, and ISO 17268 information related to nozzle/receptacles.
- 7) Heat transfer and thermal characteristics of station fuel dispensing components (i.e., fuelling lines, breakaway fittings, hose and nozzle) that are downstream of the measurement of the dispensed fuel temperature shall be estimated such that the temperature level and thermal response of the hydrogen delivered to the vehicle during dispensing can be calculated. See SAE J2601 for guidance and examples.

### A.6.3 Dispenser application considerations

The designer shall identify considerations and goals based on [6.3](#), particularly when the items affect definition of requirements in [A.6.1](#) and [A.6.2](#) or the risk assessment in [A.7](#). See [A.5.4](#).

## A.7 Fuelling protocol design and definition

The fuelling protocol and risk assessment for the specific road vehicle application shall conform with [Clause 7](#) using the requirements and considerations defined in [Clause A.6](#). The risk assessment shall comply with ISO 19880-1. See [A.5.4](#) for guidance.

The decision to utilize communications between the vehicle and the dispensing control system remains a significant decision for the fuelling of road vehicles. See [7.1](#) and [7.2](#). The designer shall decide whether communications are necessary and incorporate the result into the definition of the fuelling protocol when supported by risk assessment.

The communications, if used, shall comply with [7.2](#). See [A.5.2](#) for examples of authentication of the vehicle when required by risk assessment for hydrogen dispensing at public fuelling stations.

## A.8 Development and verification of the fuelling protocol

Development and verification of the fuelling protocol in [Clause 8](#) can be conducted by companies and/or SDOs as described in [Clause 5](#).

The developer shall verify that the fuelling protocol defined in [Clause 7](#) and [A.7](#) meets the requirements defined in [Clause 6](#) and [A.6](#). If the protocol allows alternative measures or strategies to be employed when a process deviation or fault is detected, then these possibilities shall be explored as part of the overall

verification. For example, if the fuelling protocol is designed to function without communications in the event that the communications between the vehicle and dispenser fail, then the back-up non-comm fuelling protocol shall also be verified.

Verification of the protocol shall be accomplished through a combination of analyses and tests as defined in [8.1](#). See also [B.3](#) for guidance.

Developers choosing not to use communications (UCDC of 0) or limiting communications for only data transfer, will face an extensive verification activity as defined in [8.1](#) unless the developer chooses to use a fuelling protocol such as SAE J2601 which has already been verified and extensively validated in field service. This alternative is particularly attractive when the non-comm fuelling protocol is required only as a back-up if the communication fails. Additionally, the developer can choose to lower SOC of the CHSS to further minimize risks in non-comm fuelling situations.

The use of communications between the vehicle and the dispensing control system as defined in [7.2](#) remains an attractive alternative to reduce risk and possibly reduce verification requirements. See [8.1](#) for conditions and alternative approaches to reduce verification requirements from a safety standpoint.

After completion of verification of the fuelling protocol, results of tests and analyses shall be documented and included as part of the documentation defined in [8.2](#). Instructions and other information for the implementation and check-out of the fuelling protocol in the dispensing control system (and possibly the vehicle control system) shall also be included.

## A.9 Validation of the fuelling protocol in the dispenser control systems

The objective of this clause is to validate that the fuelling protocol can be successfully implemented in a dispensing control system that is representative of targeted applications using documentation defined in [8.2](#). The hardware and software of the dispensing control system shall comply with the ISO 19880 series.

All countermeasures to process deviations and faults including branches in logic and backup fuelling protocols shall be included as part of the implementation of the fuelling protocol in the dispensing control system (when used). IEC 61508 and IEC 61511 shall be used for the design and testing of safety functions when deemed appropriate by risk assessment. IEC 62061, ISO 13849-1, and ISO 13849-2 shall also be used.

If communications between the vehicle and the dispensing system are used, then communications shall also be provided for validation testing. The control system and communications on the vehicle for UCDC levels of 2 and 3 shall comply with appropriate requirements in ISO/SAE 21434 and ISO 26262.

The validation plan and testing are as defined in [Clause 9](#). Acceptance tests in ISO 19880-1 and ISO 19880-2 shall be included as part of the validation of the fuelling protocol. See also CSA HGV 4.3 for additional guidance. If the fuelling protocol requires the sharing of information between the vehicle and dispensing system as part of pre-fuelling communications in [7.2](#) and agreement by both parties before conducting the fuelling process, then this feature shall be validated to ensure that unauthorized fuellings do not occur.

The initial validation testing of the fuelling protocol as defined above shall be performed on at least one representative dispensing control system, unless changes are made to the fuelling protocol that necessitate re-validation based on risk assessment.

NOTE 1 The above only addresses validation of the fuelling protocol (and not the dispensing system).

NOTE 2 Validation of dispensing systems for public fuelling stations of road vehicles is expected to be conducted as defined in ISO 19880-1 and ISO 19880-2.

In order to continue validation of the fuelling protocol based on operation of dispensers in the field, a mechanism shall be provided for reporting safety-related incidents and near-misses and for taking corrective actions, when required, to update the fuelling protocol and associated documentation defined in [8.2](#).

## Annex B (Informative)

### Information and Guidance for [Clauses 6](#) Through [9](#)

#### B.1 Introduction

As noted in [Clause 5](#), the focus of this document is to define the requirements necessary for the design and development of fuelling protocols. The requirements are organized into four process areas defined in [Clauses 6](#) through [9](#) (as well as [A.6](#) through [A.9](#) for road vehicles).

The intent of organizing the requirements into four process areas is to enhance understanding and not force the definition of a new and unique design and development process on the developers of the fuelling protocol. In fact, as noted in the [Clause 1](#), the requirements defined in this document are intended to be integrated by developers into their existing design and development processes to ensure that the fuelling protocol is fully verified and that the generated documentation is sufficient for the proper implementation and safe use of the fuelling protocols in dispensing systems for the targeted application.

The purpose of [B.2](#) through [B.5](#) of this annex is to provide more detailed information and guidance relative to conducting the process and meeting the requirements defined in [Clauses 6](#) through [9](#).

#### B.2 Information and guidance for the definition of fuelling protocol requirements for dispensing (in [Clause 6](#))

A clear understanding of capabilities and limitations of the fuel systems in the vehicle and the dispensing system is necessary before the fuelling protocol can be defined and developed.

Requirements can be based on applicable regulations and standards, manufacturer discussions, published reports and data, research of relevant applications, and estimates based on knowledge of the potential application.

The process starts by identifying the basic requirements for the fuelling protocol based on key objectives and limitations of the fuelling process. Specifically, with the regard to the fuelling of hydrogen vehicles, the objective of the fuelling protocol as defined in [6.1](#) is to fill the hydrogen storage containers in the vehicle fuel system during normal (fault-free) fuelling without exceeding:

- 100 % state-of-charge (SOC),
- maximum temperature of the container materials, or
- maximum fuelling pressure or maximum operating pressure (MOP).

Since the pressure of the fuel being dispensed can be used to limit the container pressure in vehicle fuel systems, the challenge of the fuelling protocol is to primarily fuel the vehicle fuel system without over-filling (above 100 % SOC) or over-heating the container materials (above maximum temperature limits).

Fuelling is further complicated when the range of capabilities and operating characteristics of both hydrogen vehicles and dispensing systems are considered. The gathering of information and the formation of requirements and specifications for operating conditions and limits into a fuelling envelope for design and development of the fuelling protocol is defined in [6.2](#) based on likely sources of the information:

- a) Fuelling requirements based on vehicle regulations and standards in [6.2.1](#)

Requirements and specifications for vehicle fuel systems can be used to define minimum capabilities and operating conditions and limits for the fuelling protocol. Product standards are also sources of

information for commercially available vehicles. For example, ISO 19881 provides general design requirements for containers in several types of land vehicles covered by this document.

- b) Requirements to be addressed by the fuelling protocol when necessary information is not available in regulations and standards in [6.2.2](#)

While regulatory requirements and product standards (in [6.2.1](#)) can provide basic information relative to the design and operation of vehicle fuel systems, additional information is often necessary over the targeted range of the hydrogen vehicles to complete definition of requirements for the fuelling protocol from a vehicle standpoint. To determine this information, estimates based on market surveys of the industry segment to be served (including discussions with manufacturers and stakeholders) can be needed to complete the compilation of necessary information of hydrogen vehicles to be fuelled.

- c) Requirements based on dispenser design and operating characteristics in [6.2.3](#)

The capabilities and limitations of the dispensing systems that will employ the fuelling protocol also need to be considered when designing the fuelling protocol. Additionally, local and regional regulations, codes, or standards can impose certain requirements that the fuelling protocol needs to address and accommodate.

These initial conditions, boundary conditions, and operating conditions, capabilities, and limitations are then synthesized into a fuelling envelope that captures worst-case combinations of vehicle, dispenser, and environmental situations that can be expected during dispensing. See [Figure B.1](#) for a simplified illustration of the resultant fuelling envelope.

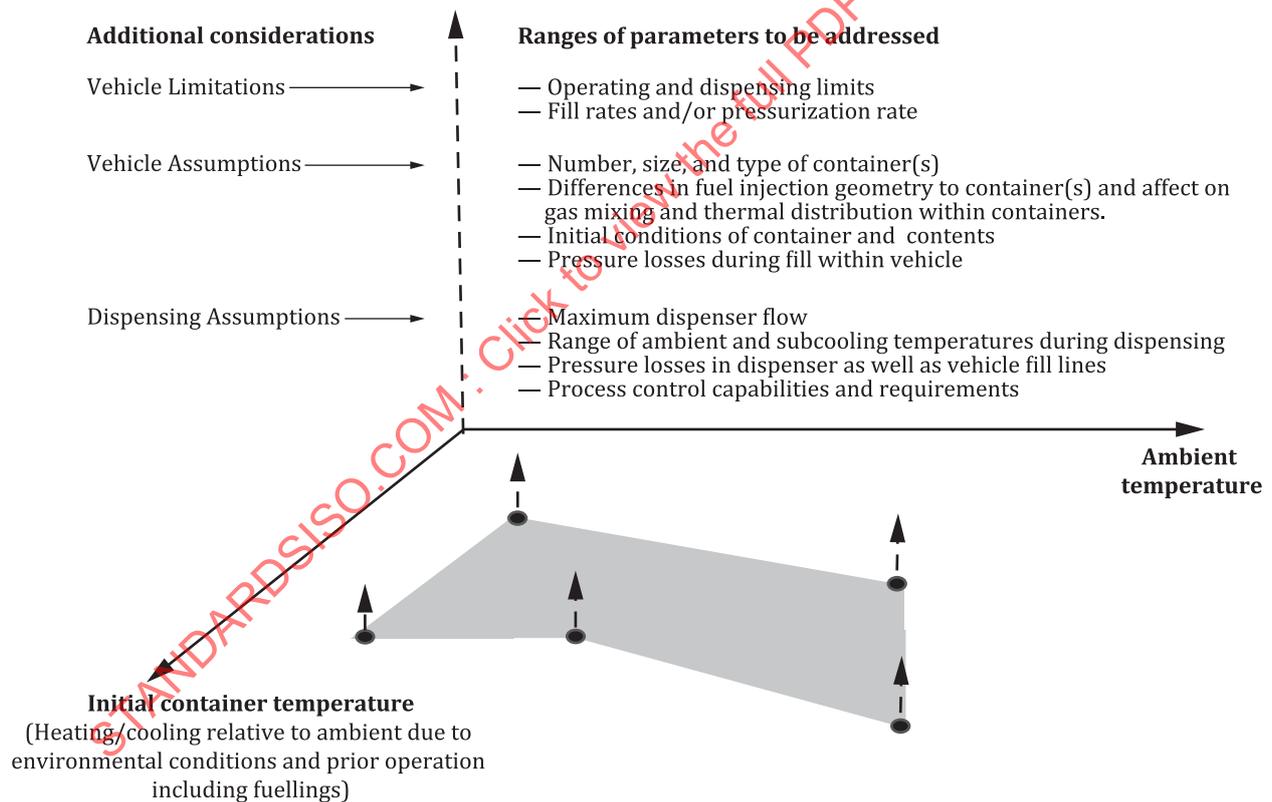


Figure B.1 — Illustration of the fuelling envelope

Understanding the targeted application can also influence the definition of the fuelling protocol. Expectations of customer and stakeholders can be defined and then used to ensure that requirements defined for the fuelling envelope in [6.2](#) are consistent with expectations. Information related to the physical and administrative actions at the fuelling station can also influence the assessment of risks during design and development in [Clauses 7](#) and [8](#).