PD ISO/TS 19880-1:2016

BSI Standards Publication

Gaseous hydrogen — Fuelling stations

Part 1: General requirements

bsi.

National foreword

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Part 1: General requirements

Carburant d'hydrogène gazeux — Stations-service —

Partie 1: Exigences générales

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Contents

Page

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 documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword – Supplementary information.

The committee responsible for this document is ISO/TC 197, *Hydrogen technologies*.

ISO/TS 19880-1 has been prepared with the ultimate goal of developing an International Standard and it replaces ISO/TS 20100:2008, on the same subject, which was withdrawn in 2015.

A list of all parts in the ISO 19880 series can be found on the ISO website.

Gaseous hydrogen — Fuelling stations —

Part 1:
General requirements

1 Scope

This document recommends the minimum design characteristics for safety and, where appropriate, for performance of public and non-public fuelling stations that dispense gaseous hydrogen to light duty land vehicles (e.g. Fuel Cell Electric Vehicles).

NOTE These recommendations are in addition to applicable national regulations and codes, which can prohibit certain aspects of this document.

This document is applicable to fuelling for light duty hydrogen land vehicles, but it can also be used as guidance for fuelling buses, trams, motorcycles and fork-lift truck applications, with hydrogen storage capacities outside of current published fuelling protocol standards, such as SAE J2601.

Residential applications to fuel land vehicles and non-public demonstration fuelling stations are not included in this Technical Specification.

This Technical Specification provides guidance on the following elements of a fuelling station (see Figure 1 and Figure 2):

— hydrogen production/delivery system

 — delivery of hydrogen by pipeline, trucked in gaseous and/or liquid hydrogen, or metal hydride storage trailers;

 — on-site hydrogen generators using water electrolysis process or hydrogen generators using fuel processing technologies;

 — liquid hydrogen storage;

 — hydrogen purification systems, as applicable;

— compression

 — gaseous hydrogen compression;

 — pumps and vaporizers;

— gaseous hydrogen buffer storage;

— pre-cooling device;

— gaseous hydrogen dispensers.

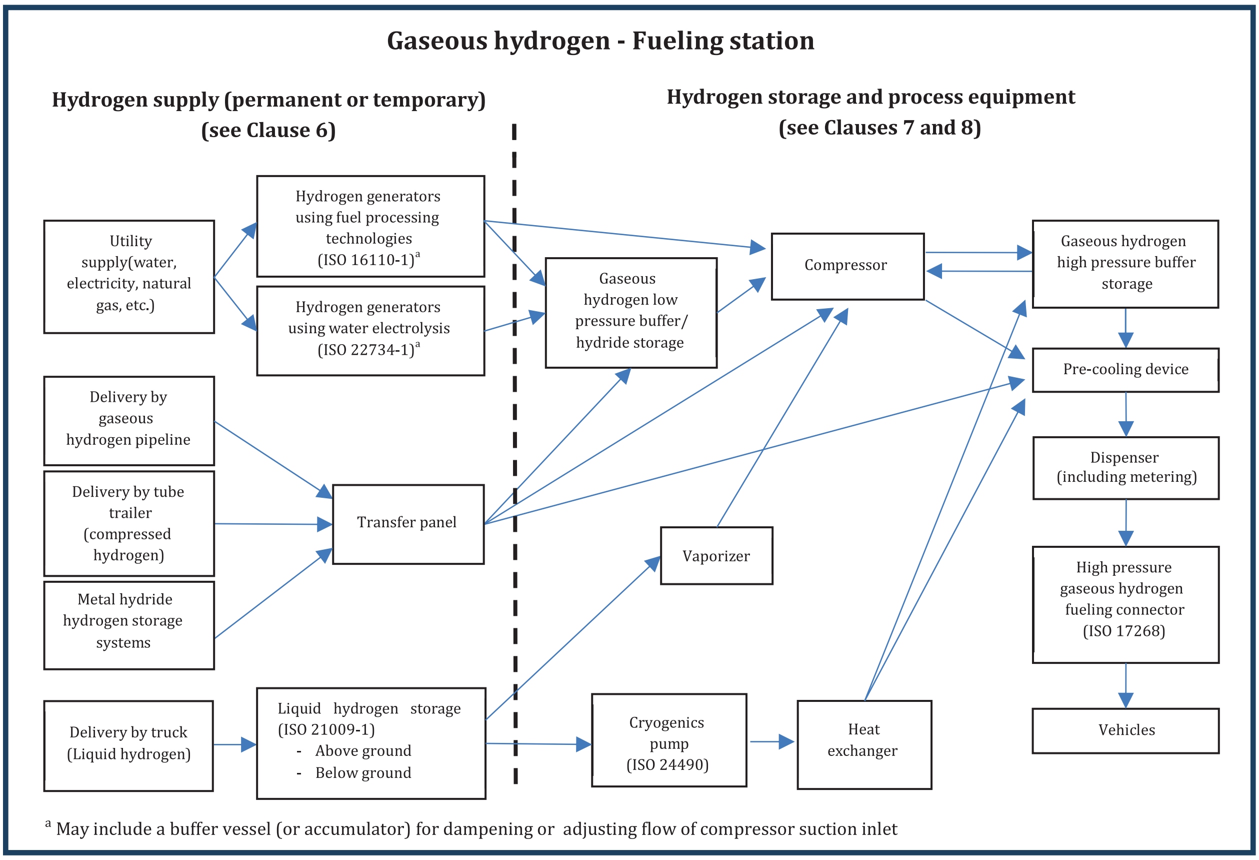


Figure 1 — Example of typical elements in a hydrogen fuelling station, including the hydrogen supply

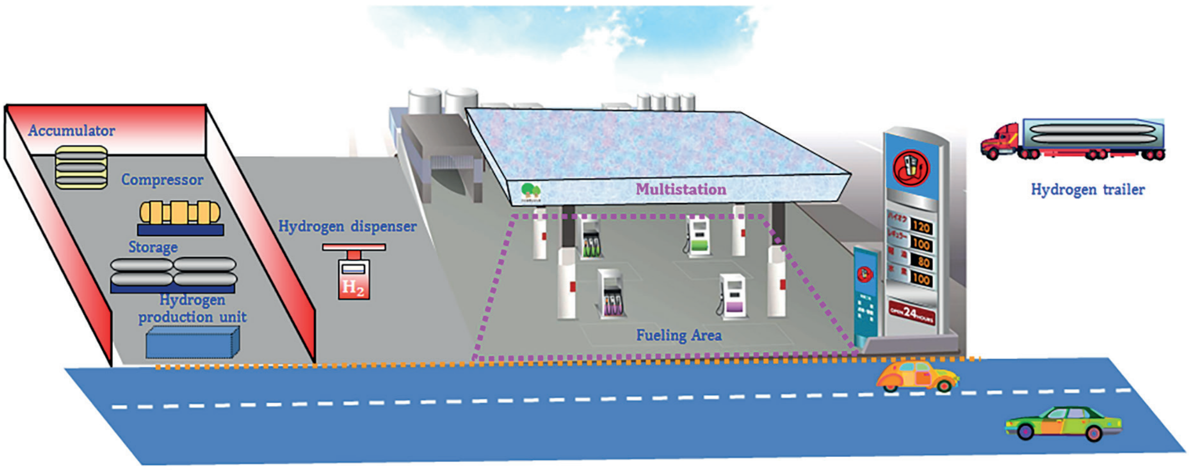


Figure 2 — Image of an example hydrogen fuelling station

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

There are no normative references in this document.

3 Terms and definitions

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

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

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

3.1
accessory
device with an operational function

3.2
authority having jurisdiction
AHJ
organization, office or individual responsible for approving a facility along with an equipment, an installation or a procedure

3.3
bleed venting
expiration or inspiration of air or gas from, or to, one side of a diaphragm of any accessory, component, or equipment such as a valve, pressure regulator or switch

3.4
breakaway device
device installed on a dispensing hose that separates when a given pull force is applied and closes the flow of hydrogen to prevent gas leakage and protect the dispenser from damage from vehicles driving away

3.5
buffer storage tanks
pressurized tanks, which can be located between a hydrogen generator and a compressor for an even flow of gas to the compressor or between the compressor and dispenser for accumulation of pressurized gas supply for vehicle fuelling

3.6
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

Note 1 to entry: A separate safety instrumented system (SIS), typically with a greater reliability than the more basic process control system (BPCS), may be required, according to the manufacturer's risk assessment, to respond solely to safety critical alarms. Further information is provided in IEC 61508 and 61511.

3.7
connector
joined assembly of nozzle and receptacle which permits the transfer of hydrogen

[SOURCE: ISO 17268:2012, 3.1]

3.8
dispenser
parts of the pressurised-gas fuelling station via which the pressurised gas is dispensed to vehicles

Note 1 to entry: As an example, the dispenser may include a dispenser cabinet, gas flow meter, a fueling hose and fueling nozzle attachments.

3.9
dispenser cabinet
protective housing that encloses process piping and may also enclose measurement, control and ancillary dispenser equipment

3.10
dispensing system
system comprising all equipment necessary to carry out the vehicle fuelling operation, downstream of the hydrogen supply system

3.11
enclosure
protective housing that may enclose, or partially enclose, equipment in order to protect it from the environment, provide noise attenuation, or provide safety to the areas surrounding the equipment

3.12
frequency
rate of occurrence of events, e.g., how many time the event occurs in a specified time or number of opportunities

3.13
fail-safe
design feature that ensures that safe operating conditions are maintained in the event of a malfunction of control devices or an interruption of a supply source

3.14
fitting
connector used to join any pressure retaining components in the system

3.15
forecourt
surfaced area where vehicle dispensing operations are conducted including the fuelling pad and any area underneath a canopy

3.16
fuel temperature
temperature of the hydrogen fuel, measured less than 1 m upstream of the dispenser hose breakaway

3.17
fuelling assembly
part of the dispenser providing the interface between the hydrogen fuelling station and the vehicle - an assembly consisting of a breakaway device, a hose(s), a nozzle and connectors between these components

3.18
fuelling hose
flexible conduit used for dispensing gaseous hydrogen to vehicles through a fuelling nozzle

3.19
fuelling pad
area adjacent to the hydrogen dispensers, where customers park their vehicles for fuelling

3.20
fuelling station
facility for the dispensing of compressed hydrogen vehicle fuel, often referred to as a hydrogen fuelling station (HRS) or hydrogen filling station, including the supply of hydrogen, and hydrogen compression, storage and dispensing systems

3.21
standalone
independent facility for the dispensing of compressed hydrogen only

Note 1 to entry: This is a type of *fuelling station* (3.20).

3.22
integrated
facility for the dispensing of compressed hydrogen integrated into an existing, or new build, conventional fuelling station

Note 1 to entry: This is a type of *fuelling station* (3.20).

3.23
fuelling station operator
person or organisation responsible for the safe operation, maintenance and housekeeping of the fuelling station

3.24
guard
part of a machine specially used to provide protection by means of a physical barrier

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

3.25
harm
physical injury or damage to the health of people, or damage to property or the environment

[SOURCE: ISO/IEC Guide 51:2014, 3.1]

3.26
harmonised standard
European standard developed by a recognised European Standards Organisation (CEN, CENELEC, or ETSI), in line with a European Directive

Note 1 to entry: harmonized standards are created following a request from the European Commission to one of these organisations. Manufacturers, other economic operators, or conformity assessment bodies can use harmonised standards to demonstrate that products, services, or processes comply with relevant EU legislation.

3.27
hazard
potential source of harm

[SOURCE: ISO/IEC Guide 51: 2014, 3.2]

3.28
hose assembly
includes the hose, appropriate end connectors (couplings or fittings), bend restrictors (if necessary), and appropriate markings

3.29
housing
section of a system that encloses, and is intended to protect, operating parts, control mechanisms, or other components that need not be accessible during normal operation

3.30
hydrogen purifier
equipment to remove undesired constituents from the hydrogen

Note 1 to entry: Hydrogen purifiers may comprise purification vessels, dryers, filters and separators.

3.31
incident
any unplanned event that resulted in injury or ill health of people, or damage or loss to property, plant, materials or the environment or a loss of business opportunity

Note 1 to entry: The use of the term incident is intended to include the term accident.

3.32
maximum allowable working pressure
MAWP
maximum pressure that a component may experience in service, including upset conditions, independent of temperature, before initiating mitigation options, typically the basis for the set point of the pressure relief device protecting the vessel or piping system

Note 1 to entry: The maximum allowable working pressure may 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: Further guidance on pressure terminology is included in Annex D.

3.33
maximum operating pressure
MOP
highest pressure that is expected for a component or system during normal operation

Note 1 to entry: This is the pressure from which hydrogen at a temperature of 85 °C would settle at the NWP at a temperature of 15 °C.

Note 2 to entry: Further guidance on pressure terminology is included in Annex D.

3.34
mechanically actuating safety equipment
mechanically actuating equipment that prevents the fuelling station operation outside specified acceptable maximum or minimum operating pressures or that prevents a gas leakage in the event of an incident

3.35
mitigation
combination of the measures incorporated at the design stage, and those measures required to be implemented by the station operator, dispenser operator, or others involved with the operation and maintenance of the fuelling station

3.36
multiple-element gas container
MEGC
multimodal assembly of cylinders, tubes or bundles of cylinders which are interconnected by a manifold and assembled within a framework, including service equipment and structural equipment necessary for the transport of gases

Note 1 to entry: This definition is taken from the UN Model Regulations. ADR uses a different definition.

[SOURCE: ISO 10286:2015, 2.2.1]

3.37
nominal working pressure
NWP
pressure for which the dispenser is intended to be operated for a given gas temperature of 15 °C

Note 1 to entry: This defines a full vehicle tank gas density, of either 35 MPa or 70 MPa at 15 °C.

Note 2 to entry: Further guidance on pressure terminology is included in Annex D.

3.38
non-public fuelling station
fuelling station (3.20)that does not sell or dispense gaseous hydrogen to the general public

EXAMPLE private or municipal vehicle fleet operation

3.39
nozzle
device connected to a fuel dispensing system, which permits the quick connect and disconnect of fuel supply to the vehicle or storage system

[SOURCE: ISO 17268:2012, 3.8]

3.40
outdoors
location outside of any building or structure, or locations under a roof, weather shelter or canopy provided this area is not enclosed on more than two sides

3.41
plinth
raised area on the forecourt, supporting and protecting the dispensers and associated equipment

3.42
positive isolation
provision of a safe environment for performing maintenance, repair or replacement operations on process facilities

Note 1 to entry: Positive isolation can be provided to equipment or piping items for maintenance purposes using various arrangements depending on following factors, as piping rating, equipment in shutdown or equipment under service.

Note 2 to entry: An assembly commonly referred to as Double Block and Bleed is often used for this purpose. For such systems, two block valves are required for additional isolation between the operational process side and the device requiring maintenance. A bleed is used to drain/vent the fluids trapped between the two block valves.

Note 3 to entry: A blind or a spade is an alternative way to provide positive isolation.

3.43
pre-cooling
process of cooling hydrogen fuel temperature prior to dispensing

3.44
pressure relief device
PRD
device designed to release pressure in order to prevent a rise in pressure above a specified value due to emergency or abnormal conditions

Note 1 to entry: PRDs can be activated by pressure or another parameter, such as temperature, and may be either re-closing devices (such as valves) or non-re-closing devices (such as rupture disks and fusible plugs). Common designations for these specific types of PRDs are as follows:

— Pressure Safety Valve (PSV) — pressure activated valve that opens at specified set point to protect a system from burst and re-closes when the pressure falls below the set point.

— Temperature-activated Pressure Relief Device (TPRD) — a PRD that opens at a specified temperature to protect a system from burst and remains open.

3.45
probability
an expression of the chance (likelihood) that a considered event will take place to property, system, business or to the environment

3.46
public fuelling station
fuelling station (3.20) that sells gaseous hydrogen to the general public

3.47
receptacle
device connected to a vehicle or storage system which receives the nozzle

[SOURCE: ISO 17268:2012, 3.11]

Note 1 to entry: This can also be referred to as a fuelling inlet of gas filling port in other documents.

3.48
risk
combination of the probability of occurrence of harm and the severity of that harm; encompassing both the uncertainty about and severity of the harm

[SOURCE: ISO/IEC Guide 51: 2014, 3.9 – added part from “encompassing” to “severity of the harm” and Note 1 to entry removed]

3.49
risk assessment
the determination of quantitative or qualitative value of risk related to a specific situation and a recognised threat (also called hazard)

Note 1 to entry: Based on national requirements, a review of a risk analysis or a safety concept by third party is sometimes required.

3.50
risk (acceptance) criteria
terms of reference by which the significance of risk is assessed

[SOURCE: ISO/IEC Guide 73:2009, 3.3.1.3]

3.51
risk level
the assessed magnitude of the risk

3.52
safeguarding
use of specific technical means to protect persons from the hazards which cannot reasonably be removed or sufficiently limited by design

3.53
safety
freedom from unacceptable risk

[SOURCE: ISO/IEC Guide 51:2014, 3.14]

3.54
safety device
device other than a guard, which eliminates or reduces risk, alone or associated with the guard

3.55
safety distance
distance to acceptable risk level or minimum risk-informed distance between a hazard source and a target (human, equipment or environment), which will mitigate the effect of a likely foreseeable incident and prevent a minor incident escalating into a larger incident

Note 1 to entry: Safety distances are split into Restriction distances, Clearance distances, Installation layout distances, Protection distances and External risk zone. See 5.8.2 for further details.

Note 2 to entry: The term “safety distance” may also be referred to as “safe distance,” “separation distance,” or “setback distance.”

3.56
safety function
function to be implemented by a control system or safety-instrumented system, which is intended to achieve or maintain a safe state for the process with respect to a specific hazardous situation

Note 1 to entry: Other technologies or risk reduction measures have a safety function not achieved through a control system, however validation of these measures is equally important.

3.57
safety-instrumented system
instrumented system used to implement one or more safety instrumented functions

Note 1 to entry: A safety instrument system is composed of any combination of sensors, logic solvers and final elements.

3.58
safety-related system
designated system that both implements the required safety functions necessary to achieve or maintain a safe state for the EUC and is intended to achieve, on its own or with other E/E/PE safety-related systems, other technology safety-related systems or external risk reduction facilities, the necessary safety integrity for the required safety functions

Note 1 to entry: The term refers to those systems, designated as safety-related systems, that are intended to achieve, together with the external risk reduction facilities (IEC 61508-5:2010, 3.4.3), the necessary risk reduction in order to meet the required tolerable risk (IEC 61508-5:2010, 3.1.6 and Annex A).

Note 2 to entry: The safety-related systems are designed to prevent the EUC from going into a dangerous state by taking appropriate action on receipt of commands. The failure of a safety-related system would be included in the events leading to the determined hazard or hazards. Although there may be other systems having safety functions, it is the safety-related systems that have been designated to achieve, in their own right, the required tolerable risk. Safety related systems can broadly be divided into safety-related control systems and safety-related protection systems, and have two modes of operation (IEC 61508-5:2010, 3.5.12).

Note 3 to entry: Safety-related systems are potentially an integral part of the EUC control system or interface with the EUC by sensors and/or actuators. That is, the required safety integrity level is achieved by implementing the safety functions in the EUC control system (and possibly by additional separate and independent systems as well) or the safety functions may be implemented by separate and independent systems dedicated to safety.

Note 4 to entry: A safety-related system is designed:

a) to prevent a hazardous event (i.e. if the safety-related systems perform their safety functions then no hazardous event arises);

b) to mitigate the effects of the hazardous event, thereby reducing the risk by reducing the consequences;

c) to achieve a combination of a) and b).

3.59
state of charge
SOC
ratio of compressed hydrogen storage system (CHSS) hydrogen density to the density at maximum operating pressure rated at the standard temperature 15 °C

Note 1 to entry: SOC is expressed as a percentage and is computed based on the gas density according to formula below.

Note 2 to entry: The accuracy of the NIST formula has been quantified to be to within 0,01 % from 255 K to 1 000 K with pressures to 120 MPa at the publishing of this document.

$$SOC(\%) = \frac{\rho(P,T)}{\rho(NWP, 15°C)} x100$$

Note 3 to entry: The hydrogen densities at the two major nominal working pressures are:

— density of H_2 at 35 MPa and 15 °C and = 24,0 g/l

— density of H_2 at 70 MPa and 15 °C and = 40,2 g/l

Note 4 to entry: The ρ(P,T) function for hydrogen is available from the National Institute of Standards and Technology (NIST) at http://www.boulder.nist.gov/div838/Hydrogen/PDFs/Lemmon.2008.pV113.N06.A05.pdf

3.60
station pressure
pressure of the hydrogen gas supplied to the vehicle by the station, measured near the hose breakaway

3.61
target pressure
station pressure that the hydrogen fuelling protocol targets for the end of fuelling

3.62
vaporizer
device other than a tank that receives hydrogen in a liquid form and adds sufficient heat to convert the liquid to a gaseous state

4 Abbreviated terms

AHJ Authority Having Jurisdiction

AiCHE American Institute of Chemical Engineers (AIChE)

ALARP As Low As Reasonably Practicable

API American Petroleum Institute

CEN French: Comité Européen de Normalisation (European Committee for Standardization)

CENELEC French: Comité Européen de Normalisation Électrotechnique (European Committee for Electrotechnical Standardization)

CFD Computational Fluid Dynamics

CHSS Compressed Hydrogen Storage System

ESReDA European Safety, Reliability and Data Association

ETSI European Telecommunications Standards Institute

LFL Lower Flammability Limit

MAWP Maximum Allowable Working Pressure

MEGC Multiple Element Gas Containers

MOP Maximum Operating Pressure

NWP Nominal Working Pressure

OGP Oil and Gas Producers

OREDA Offshore and onshore REliability DAta

QRA Quantitative Risk Assessment

PRD Pressure Relief Device

PSD	Pressure Safety Device
PSV	Pressure Safety Valve
SOC	State of Charge
TPRD	Temperature-activated Pressure Relief Device
VCE	Vapour Cloud Explosion

5 General safety recommendations

5.1 Hydrogen fuelling station safety recommendations

The hydrogen fuelling station installation should be sited to minimize risk to users, operating personnel, properties, and the environment. The following elements of a hydrogen fuelling station should be considered potential hazard sources:

- on-site hydrogen production unit;
- hydrogen delivery system, including remote fill points as applicable;
- compressors;
- storage;
- piping;
- dispensing units.

More specifically, the hydrogen fuelling station should include measures to reduce harm from the following hazards:

- fires, deflagrations, detonations and blast waves;
- asphyxiation hazard (due to release of gaseous hydrogen or inert gases in confined spaces);
- cryogenic burns (liquid hydrogen supply);
- impact from pressure / debris;
- any additional hazards associated with the system, including:
  - electrocution hazards;
  - working at heights (e.g. roof mounted equipment);
  - injury from moving equipment / hose whip.

The following three stages of safety assurance should be considered:

- prevention of accidents through a combination of the following:
  - application of state of the art technology;
  - following technical standards and simple handling procedures to users and operators;
  - designing the user-machine-interfaces in a straight forward manner;
  - emphasizing training of personnel, managing competence of personnel;
  - implement Management of Change processes;

  - establishing preventative maintenance.
- mitigation strategies by combination of the following:
  - application of state of the art technology;
  - barriers and layers of protection;
  - safety measures;
  - safety distances.
- structured and effective emergency response (contingency planning).

In general, the following mitigation strategies should be considered:

- minimization of the potential for the formation of a flammable or explosive mixture;
- minimization of the potential for ignition (from both piloted and spontaneous ignition sources);
- mitigation of the effects of a fire or explosion originating from the fuelling station installation;
- mitigation of the impact to the fuelling station installation from an external fire;
- reduction of the physical effects of the explosion strength potential of explosive atmosphere generated by potential leaks or releases.

5.2 Risk assessment

Risk assessment may be used as a flexible compliance option. Use of risk assessment allows station owners and designers to flexibly define station-specific mitigations that achieve an equal or better level of safety to those of prescriptive recommendations.

Risk assessment is the overall process of risk identification, risk analysis, risk evaluation and risk mitigation. Risks can be assessed at an organizational level, at a departmental level, for projects, individual activities or specific risks. A risk assessment should be performed for the hydrogen fuelling station in accordance with one of the following standards: ISO 31000, ISO/IEC 31010, and/or ISO 12100.

Methods used in assessing risks can be qualitative, semi-quantitative or quantitative. The degree of detail required will depend upon the particular application, the availability of reliable data and the decision-making needs of the organization. Some methods and the degree of detail of the analysis may be prescribed by legislation.

It is recommended that the risk assessment carried out for the hydrogen fuelling station should be quantitative or semi-quantitative. Recommendations for the method, degree of detail, and source of information used in the assessment when carried out specifically for a hydrogen fuelling station are included in 5.3 and 5.4.

Qualitative assessment defines consequence, probability and level of risk by magnitude levels such as “high”, “medium” and “low”, may combine consequence and probability, and evaluates the resultant level of risk against qualitative criteria.

Semi-quantitative methods use detailed models and data for either consequence or probability, and qualitative treatment for the other. One example is a “consequence only” analysis which uses detailed consequence modelling and assumes the probability of a scenario is 1,0.

Quantitative analysis uses detailed models and data to estimate for consequences and their probabilities, and produces values of the level of risk using both probability and consequence. Level of risk is expressed in specific units defined when developing the context.

5.2.1 Methodology for semi-quantitative and quantitative risk assessment for assessing hydrogen installation safety

5.2.1.1 General

It may be possible to use Quantitative Risk Assessment (QRA) and/or semi-quantitative (e.g., consequence-only) analysis instead of prescriptive requirements to allow the hydrogen fuelling station to use alternative methods which are of an equivalent, or higher, level of safety to the prescriptive requirements. Using QRA may allow (for instance using mitigation measures) for shorter safety distances and/or simplified station layout.

If QRA is used, this clause provides recommendations for performing that analysis. This analysis focuses on at hazards involved with the release and ignition of hydrogen mixtures and related physical effects. This does not cover non-hydrogen hazards associated with the fuelling station, see 5.10.

Developing an approach to protect against harm should consider the following factors:

— nature of the hazards (e.g., thermal, pressure, toxicity, etc.);

— physical properties of hydrogen under the design and operating conditions;

— equipment design and operating conditions;

— installation design and location, including protection measures;

— targets (e.g., person, property, equipment) which are being protected from effects of potential hazards.

A semi-quantitative risk assessment provides an intermediary level between the textual evaluations of qualitative risk assessment and the numerical evaluation of quantitative risk assessment, by evaluating risks with a score. Semi-quantitative risk assessment provides a structured way to rank risks according to their probability, severity or both (criticality), and for ranking risk reduction actions for their effectiveness. This is achieved through a predefined scoring system that allows one to map a perceived risk into a category, where there is a logical and explicit hierarchy between categories. Semi-quantitative risk assessment is generally used where one is attempting to optimize the allocation of available resources to minimize the impact of a group of risks.

It helps achieve this in two ways:

— first the risks can be placed onto a sort of map so that the most important risks can be separated from the less important;

— second, by comparing the total score for one or a series of risks before and after any proposed risk reduction measures, so one can get a feel for how relatively effective the mitigation strategies are and whether they merit their costs.

For performing a semi-quantitative risk assessment, a full mathematical model is not always needed. It could sometimes offer the advantage of being able to evaluate a larger number of different kind of risk issues in a limited time. Nonetheless, all forms of risk assessment require the greatest possible collection and evaluation of data available on the risk issue.

5.2.1.2 Summary of methodology

Risk assessment provides a framework to establish a common understanding of the system safety level based on robust science and engineering models. The process enables transparent, evidence-based safety decisions. The QRA approach uses a combination of probabilistic and deterministic models to evaluate potential consequences on the targets identified in the previous clause. Risk is characterized by a set of hazard exposure scenarios, the causes associated with each scenario, the undesirable consequences associated with the scenario, and uncertainty about these elements (this uncertainty is generally expressed by probability). In consequence-only modelling, the probability term is ignored, but the remainder of the analysis follows the same methodology.

One major aim of risk assessment is to provide a description of the hazard scenarios, their causes and consequences and uncertainties (taken in part or in whole), for use in decision making (e.g., comparison against a defined risk acceptance criteria).

The process for risk-informing mitigations includes the following steps, as displayed in Figure 3:

— target determination– Define the targets being protected, and as necessary, the hazard sources. Table 3 provides many examples of targets;

— analysis scoping – Select appropriate risk type for each target and establish tolerability criteria (e.g., acceptable/unacceptable risk level) for each target;

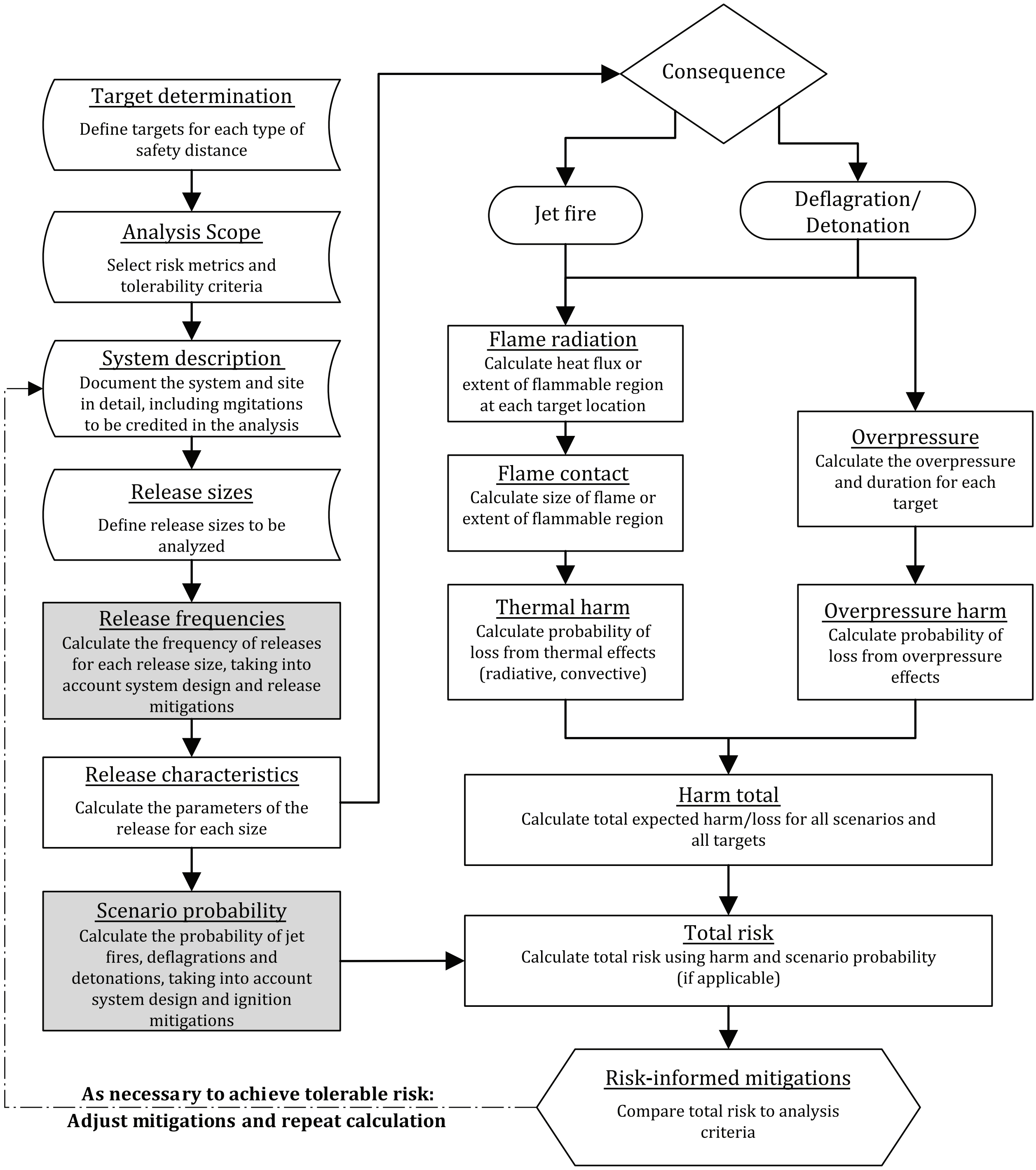
— system description – Document the system and installation being analysed, including mitigations to be credited in the analysis and which events they mitigate (see 5.1);

— cause analysis – Identify and model the hazard scenarios and quantify the probability of each scenario in the model for each source and target;

— consequence analysis – Identify the physical effects for each scenario, and quantify the impact of those effects on the targets;

— risk assessment – Integrate the cause and consequence models into an assessment of the total risk; Perform sensitivity studies and changing modelling assumptions to identify appropriate combination of mitigation elements to maintain risk level within the tolerability region;

— risk-informed mitigations -- Increase or reduce mitigations to achieve risk level within tolerability region (including consideration of uncertainty).



- Grey shading denotes an analysis step that is used only in full -QRA approach
- Concave rectangle denotes analysis step
- Rectangle denotes calculation step
- Diamond denotes branching

Figure 3 — Example of a risk-informed approach to safety distances

5.2.1.3 Target determination and analysis scoping

Each characterisation of safety distance in Table 1, affects one or more classes of target. Table 3 provides many examples of targets for each type of safety distance. Types of safety distance should be defined according to national requirements / guidance, with appropriate targets and hazards sources defined for each type of safety distance.

5.2.1.4 Hazards

The primary hazards related to the use of hydrogen are the release and subsequent ignition of hydrogen. The two main hazards are thermal effects (e.g. conduction or radiation from hydrogen flames or post flame gases) and blast effects (overpressure and impulse) from deflagrations and detonations. Both of these hazards should be modelled for all sources and all targets.

5.2.1.5 Risk and harm criteria and tolerability limit selection

Risk and harm criteria are established through close interactions with stakeholders, which may include detailed surveys of existing risk benchmarks. A best practice is to ensure that risk from hydrogen fuelling should be equal to or less than the risk posed by similar activities, which could include gasoline fuelling, occupational accidents, general accident rates within the population, etc.

For personnel risk, including workers and/or members of the general public, four widely used fatality risk criteria are:

— FAR (Fatal Accident Rate) – the number of fatalities per 100 million exposed hours;

— AIR (Average Individual Risk) or Individual risk per annum - the individual risk averaged over the population which is exposed to risk from the facility;

— PLL (Potential Loss of Life) – the average number of fatalities (per system-year);

— F-N curves representing the expected frequency at which *N* or more people will be exposed to a fatal hazard (cumulative distribution function). Such curves may be used to express societal risk criteria.

Other criteria may be used, such as:

— average number of hydrogen releases per system-year;

— average number of jet fires per system-year;

— average number of deflagrations/detonations per system-year.

Consequence-based harm or damage criteria may be used, such as:

— heat flux level;

— thermal dose;

— flame temperature;

— flame length;

— peak overpressure;

— gas concentration;

— fluid temperature.

Acceptance criteria should be specified. These may be specified in terms of single values, acceptance bounds or distributions, use of ALARP (As Low As Reasonably Practicable), option comparison, etc.

Due to the complexity and uncertainties involved in predicting performance in engineered systems, there will always be a level of subjectivity attached to any risk assessment result. This uncertainty should be considered when selecting risk and harm criteria and tolerability limits.

5.2.1.6 System description

The analysis should contain documentation of the installation and operational environments (as-built and as-operated). Documentation should contain sufficient detail to allow replication by an independent expert.

The documentation should define and identify the system, and components, their functions, and their relationships and interfaces. Block diagrams, P&IDs, and other figures should be included to facilitate understanding of the boundaries of the system, components of the system, and functions of each component in each operational environment. Installation characteristics should be described, including expected use conditions and layout diagrams. Expected operating parameters/states of hydrogen in the system should be documented.

The scope of work should capture and define the work activities and intended applications. If multiple operational environments are contained in one analysis, the work activities should be defined for each operational environment.

5.2.1.7 Cause analysis

The goal of cause analysis is to provide insight into the causes of hazardous exposures and the likelihood of those causes. This involves creating models that describe the scenarios that occur after a release of hydrogen, and quantifying these models using probability information.

5.2.1.8 Exposure scenarios

At a minimum, exposure scenarios should contain the following elements:

— release of hydrogen. Release sizes that are to be modelled should be defined based on national requirements or guidance;

— occurrence of ignition. At a minimum, ignition should be sub-divided into immediate and delayed ignition;

— jet fires, deflagrations/detonations.

Root causes of releases should be identified qualitatively. Use of root cause information in quantification is optional. Root causes should include:

— leaks from individual components, including separation of a component or unintended operation;

— shutdown failures;

— accidents, including collisions and drive-offs;

— human errors.

Scenario and root cause models may also include:

— leak detection systems;

— system isolation;

— more detailed bifurcations of “ignition”.

For QRA, exposure scenario fault expressions may be documented graphically, e.g. in Event Trees or Event Sequences Diagrams, or fault expressions can be manually specified. Root causes may be given as a list, or documented graphically, e.g. in Fault Trees, or through fault expressions.

5.2.1.9 Data for scenario quantification

Data used should be of sufficient quality to support decision making. Sources of data should be documented in the analysis.

Analysts should use published, hydrogen-specific data if it is available.

Non-published, hydrogen-specific data, such as proprietary company-specific data, may be used. If such data are used, the data should be documented and should be made available to the AHJ or designated reviewer if requested. The designated reviewer should give extra scrutiny on inputs that lower probabilities below commonly used data sources.

In lieu of hydrogen-specific data, commonly accepted, published data sources (OREDA, ESReDA, AiCHE or API 521) from similar industries and applications should be used.

5.2.1.10 Consequence analysis

This involves determining the physical effects of the scenarios, as well as the target response to those physical effects.

5.2.1.11 Physical effects of the accidents

The physical effects of hydrogen fires which should be modelled for a target are 1) thermal effects and 2) pressure effects. The primary physical effects relevant to ignited hydrogen releases are fire effects (for example; impinging flames, high temperature, heat flux) and explosion effects such as pressure and impulse waves.

NOTE Debris effects (e.g., from over-pressurization of hydrogen vessel) are not required to be modelled.

Modelling of these required physical effects requires modelling several physical processes: release, jet flames, and deflagrations and detonations.

The physical models used should be validated for use in on hydrogen within the parameter ranges expected in the fuelling installation or specific equipment.

5.2.1.12 Hydrogen release characteristics

The first step in characterizing consequences is to characterize the release of hydrogen and the extent of the flammable envelope. Thermodynamic parameters of releases from high-pressure hydrogen systems can be estimated using notional nozzle models. The selected model should be validated for use in high-pressure hydrogen systems within the parameter ranges expected in the fuelling installation or specific equipment. The selected model should be specified in the analysis documentation.

5.2.1.13 Ignition sources

The source of ignition for an installation or the process itself should be examined. A non-comprehensive list of examples is as follows:

— lightning

— static electricity (including clothing)

— mechanical sparks (for example; moving parts, tools not suitable for explosive atmospheres)

— naked flames

— hot surfaces (for example; overheating by adiabatic compression)

— electrical components and installations (for example; electric sparks)

— exposed live cables

5.2.1.14 Jet flame behaviour

Releases from high-pressure hydrogen systems that are ignited immediately produce momentum driven jet flames. A validated hydrogen model should be used to predict the characteristics of a jet flame necessary to meet the goals of the analysis. The selected characteristic(s) should be specified in the analysis documentation. Characteristics relevant to the goals of the analysis may include flame length, flame width, or heat flux. The position at which these characteristics are calculated should be specified in the analysis.

5.2.1.15 Deflagration and detonation behaviour

Releases from hydrogen systems which are not immediately ignited may accumulate and result in a flash fire, blast or vapour cloud explosion (VCE) when ignited with thermal and pressure effects.

Thermal and overpressure effects created from hydrogen deflagration or detonation can vary significantly based on the scenario.

The least significant is a flash fire when the cloud is ignited in its extremity (regions below 10 % of hydrogen). Flash fires result in thermal effects with very small overpressure.

When the cloud is important and ignition near the central stoichiometric region, the overpressure effects (and associated impulse) produced could be more important.

The turbulence in the hydrogen release, and/or the presence of objects can potentially result in an increase of the overpressure generated.

Blast effects may be modelled using validated software code based on Computational Fluids Dynamics (CFD), empirical or Phenomenological methods.

5.2.1.16 Harm models

A harm or damage model or criteria is used to translate the physical effects into the harm to a person, a component, or structure. This should be done through use of either a model or criteria, including single criteria, deterministic models, probability models, probit functions. The selected criteria or model may come from reference to establish scientific information or national standard. The selected model or criteria should be specified in the analysis documentation.

5.2.1.17 Risk calculation

Some forms of risk assessment calculate risk for multiple individual scenarios and some use one calculation of risk for multiple scenarios.

When the total risk for the system is required, this should be calculated by combining the results of the scenario (cause) analysis and the consequence analysis into the total.

Risk is expressed as follows:

$$Risk = \sum_n \left(f_n * C_n \right)$$

where risk is summed over all n selected scenarios, f_n is the frequency of scenario n, and c_n is the consequence for scenario n.

Risk may be calculated separately for each type of consequence (e.g., harm, loss).

In all cases, a combination of risk analysis and consequence only analysis may be used. For example, an AHJ may ask for a consequence only analysis for additional specific scenario and an AHJ may ask for a total risk analysis to include additional scenario.

5.2.1.18 Risk-informed mitigations

The estimated risk level should be compared to the risk acceptance criteria.

If the estimated risk level is above the acceptance criteria, the analyst should implement additional mitigations or increase safety distances to reduce the risk level, and re-run the analysis.

If the estimated risk level is below the acceptance criteria, the mitigations or safety distance may be reduced.

Analysts should consider/discussion appropriate methods to account for uncertainty when comparing to risk criteria. This should be addressed through use of conservative risk criteria, or sensitivity analysis or methods to propagate uncertainties.

5.3 Mitigation measures to improve system safety

The risk assessment should demonstrate that the mitigation measures are appropriate to achieve the desired reduction of the probability and/or consequences of each scenario. Mitigations which improve overall safety of the system (as demonstrated by use of the quantitative risk assessment process defined above) may be used to:

— reduce prescriptive safety distances through the risk-informed safety distance process;

— relax existing prescriptive mitigation measures by carrying out a semi-quantitative or quantitative risk assessment.

As long as total system risk remains below the selected tolerability threshold (Risk acceptance criteria).

Several mitigation features affect the probability and/or impact of multiple aspects of the analysis (e.g., use of enclosures can reduce the probability of ignition, but it could potentially increase the consequence of deflagrations) – when credit is taken for a mitigation, the entire analysis should be re-run to ensure that total risk is sufficiently low.

5.4 Mitigations which reduce the potential for the formation of a flammable or explosive mixture

5.4.1 General

Hydrogen fuelling stations should be designed and operated such that, where an intentional or unintentional release of flammable gas occurs during normal operation, the formation of a flammable or explosive atmosphere is prevented, minimised, detected or controlled. Further detailed information is available from the IEC 60079 series of standards.

Where possible, it may be preferable to locate hydrogen process equipment in the open air, with natural ventilation to dissipate any leaked hydrogen. Alternatively the hydrogen equipment may be located in an enclosure to permit detection of leaks and instigate forced ventilation to prevent accumulation.

The following mitigations may reduce the frequency or probability of a release

— equipment designs which minimize the number of connections, are leak-free by design or use inherently safe equipment design;

— permanent inert atmosphere;

— in-process leak detection such as the ability for isolated systems to hold pressure;

— regular inspections and maintenance.

The following mitigations may reduce the frequency of scenarios related to gas accumulation (delayed ignition scenarios)

— hydrogen detectors to provide detection and automatic shutdown/isolation if flammable mixtures present, particularly in enclosed spaces;

— ventilation (e.g. passive or active ventilation).

Where the source of release is situated outside an area or in an adjoining area, the penetration of a significant quantity of flammable gas or vapour into the area can be prevented by suitable means such as:

— physical barriers;

— maintaining a sufficient overpressure in the area relative to the adjacent hazardous areas, so preventing the ingress of the explosive gas atmosphere;

— purging the area with sufficient flow of fresh air, so ensuring that the air escapes from all openings where the flammable gas or vapour may enter.

5.4.2 Hydrogen detection systems

Hydrogen detection apparatus used in hydrogen sensing and monitoring systems should comply with, and meet the accuracy requirements of ISO 26142.

Hydrogen detection apparatus and/or hydrogen detection systems should have a suitable range for the concentration set-points used to initiate a response through the control or safety system.

When used, hydrogen detection apparatus should be installed where it has the highest likelihood of detecting the foreseeable leaks, such as:

— upstream of the ventilation system;

— where the released hydrogen is most likely to accumulate.

The appropriate response should be determined by the manufacturer’s risk assessment.

This may include different activation limits, for example:

— a lower activation limit, set at a maximum value of 25 % of the lower flammability limit (LFL), which instigates further mitigation measures and alerts the fuelling station operator, and other users. An alarm set point lower than 25 % LFL may be appropriate depending on the station risk assessment, for example, for enclosed areas with a high level of congestion;

— a higher activation limit, set at a maximum value of 50 % of LFL, which instigates an emergency shutdown and alerts the fuelling station operator, and other users. An alarm set point lower than 50 % LFL may be appropriate depending on the station risk assessment, for example, for enclosed areas with a high level of congestion.

Further mitigation measures that may be appropriate to be taken upon detection of a flammable atmosphere above the lower activation limit include, but are not limited to:

— shut off of the hydrogen supply to the equipment within the enclosure from an isolation point outside of the container;

— depressurisation of the hydrogen equipment within the enclosure to a safe location;

— de-energization of electrical equipment not intended for use in flammable atmospheres;

— increased ventilation.

The duration of the audible and visual signals instigated by the hydrogen detection system should be determined by the manufacturer’s risk assessment. Where safe to do so, it is recommended that the visual signals should remain until the alarm condition has been corrected and the fuelling station control or safety system has been manually reset. The audible signals may be automatically extinguished when the concentration of hydrogen falls below a defined set-point, after a specified period of time or when the control system is manually reset.

5.4.3 Safety and emergency shut-off systems

In order to minimise the magnitude of an unintentional release, or to minimise the duration of the flammable or explosive atmosphere, emergency isolation valves that can safely shut-off the hydrogen supply from the hydrogen storage to other areas of the hydrogen fuelling station should be installed.

The fail-safe position of automatic valves in liquid hydrogen lines in the event of power or pneumatic pressure loss should be defined by risk assessment and implemented accordingly.

5.4.4 Mitigation for the formation of a flammable or explosive mixture in enclosures

The formation of hazardous explosive atmospheres resulting from anticipated hydrogen leaks or releases in enclosures should be minimised when practical.

NOTE 1 When this is not practical, see 10.2 for guidance on classifying hazardous areas and controlling ignition sources within the hazardous area.

A non-comprehensive list of example prevention methods is as follows:

— passive ventilation;

— active ventilation;

— flammable gas detection system or ultrasonic gas detection;

— integrity testing (rate of pressure loss measurement) of isolated piping sections;

— other means of leak detection.

Where passive or active ventilation is relied upon for preventing ignitable mixtures, the ventilation rate should maintain a volume fraction below 25 % of the lower flammability limit (LFL) of hydrogen or any other flammable gases (see 5.4.2). Where continuous or primary grades of release, as defined in IEC 60079-10-1, are anticipated, a lower volume fraction may be appropriate.

Small dilution volumes where the structural integrity of the enclosure would not be affected in case of ignition, based on the maximum anticipated flammable gas leak rate into the enclosure as determined by the manufacturer, may be exempted from this requirement. The manufacturer should demonstrate that the equipment is fit for the purpose.

This rate of ventilation need not be permanently present if it is initiated by a flammable gas detection system upon measurement of the lower activation limit complying to the recommendations of 5.4.2 However, the rate of ventilation necessary to prevent the formation of an explosive atmosphere due to normal and expected releases (e.g. natural leaks from fittings, or hydrogen permeation through non-metallic materials), should be maintained whenever the process contains hydrogen under pressure, whether the system is in operation or not.

Whenever active ventilation is used, the minimum required ventilation rate of the ventilation system should be specified. The pressure drop across the ventilation system and the maximum outlet pressure of the ventilation system should be taken into account as important design criteria.

Enclosures containing non-classified electrical equipment, not suitable for operation in a hazardous area, that rely on active ventilation for protection against the formation of a flammable atmosphere should be purged with sufficient air changes prior to the energization of such equipment.

Failure of active ventilation or detection of flammable gas in an enclosure at the maximum volume fraction of 25 % of the LFL of hydrogen or any other flammable gases present should cause the shut-off of the supply of hydrogen and other flammable gases to the enclosure and the de-energization of non-classified electrical equipment.

Computational fluid dynamics analysis, using calculation tools validated for hydrogen, physical testing using a tracer gas, or similar methods given in IEC 60079-10-1, may be used to design the means of active and/or passive ventilation and the means of hydrogen detection for providing the required protection.

NOTE 2 Sudden and catastrophic failure of vessels or piping systems need not be considered a leak scenario in this analysis when protection against such failures has already been contemplated in the tank and piping design.

Area classification determined according to 10.2 and the protection recommendations for equipment in classified areas may be adjusted taking into account the means of ventilation and the means of flammable gas detection that are present. In all cases, electrical apparatus operating in dilution volume that can exist near potential sources of release (leaks points) should be protected in accordance with 10.2.2.

Enclosures should be designed so as to avoid high points where hydrogen can accumulate undetected.

5.4.5 General requirement hydrogen venting for mitigation for the formation of a flammable or explosive mixture

Flows from vents and safety relief equipment should be piped outdoors to a safe location to avoid formation of a flammable or explosive mixture in hydrogen equipment enclosures or other locations where the consequences of ignition of the vented hydrogen would pose a hazard.

The position of hydrogen vent stacks should be taken into account in the layout of the installation and should be such that the vent may be used for operation, maintenance and emergency response without creating hazardous conditions. Consideration should be given to the temperature of the hydrogen that is vented, and the effect that this can have on the density of the vented gas.

The vent outlet location should be arranged to discharge to open air, and so as not to generate a hazard for persons or neighbouring structures, away from personnel areas, electrical lines and other ignition sources, air intakes and building openings. The vent stack should not discharge where accumulation of hydrogen can occur, such as below the eaves of buildings.

Hydrogen dispersion and radiated heat calculations should be carried out to establish the location and height of vent stack exits. Further detail is provided in 5.8.4.

The outlet of the vent stacks should not be equipped with devices that deflect the direction of the vented hydrogen downwards.

5.5 Mitigations which reduce the potential for ignition

5.5.1 General

The following mitigations may reduce the probability of ignition:

— restriction of activities;

— area classification;

— design by construction of components or equipment;

— electrical measures; (e.g., grounding and bonding)

— equipment enclosures;

— procedures. (e.g. anti-static clothes or non-sparking tools, limited access)

5.5.2 Areas subject to restriction of activity

Equipment or areas of the hydrogen fuelling station in which flammable materials are handled or stored should be designed, operated and maintained so that any releases of flammable material, and consequently the extent of potentially explosive atmospheres, are kept to a minimum with regard to frequency, duration and quantity, whether in normal operation or otherwise.

In a situation in which there may be an explosive gas atmosphere, the following steps should be taken:

— minimise the likelihood of an explosive gas atmosphere occurring around the source of ignition;

— minimise the likelihood of potential sources of ignition being present.

This may be achieved through the control of ignition sources in the potentially explosive atmospheres by the restriction of activities within defined distances, referred to as "restriction distances", and by the implementation of a hazardous area, as classified according to IEC 60079-10-1, in which fixed electrical equipment should be appropriately classified, see 10.2.2.

Areas where restrictions on ignition sources should be implemented are applicable from points of potential releases of hydrogen and/or other flammable fluids, or from the exhaust of passive or active ventilation of enclosures around equipment containing flammable fluids. In some cases the distances from the potential release source where activities should be restricted (restriction distances) are equivalent to the hazardous area as defined according to IEC 60079-10-1, in other cases the restriction distances may be determined by other methodologies.

Only authorized persons should be allowed to enter such areas. They should be aware of the hazards potentially encountered and the relevant emergency procedures.

Restriction of activity does not apply to the dispenser area, for which specific risk assessment may allow access to dispensers without any restrictions.

All portable equipment which may generate an ignition source when brought into the restricted access area (i.e. portable lamps, flashlights, communication devices) should comply with the safety recommendations for use in hazardous areas.

Maintenance operations requiring the generation of an ignition source within the restriction distances while the installation is in operation or pressurized with hydrogen should only be performed in case of service necessity where hydrogen presence in the atmosphere is not likely under normal conditions. During such operations, the atmosphere in the work area should be continuously analysed using a portable analyser. Welding and grinding should be done with the utmost care. Hydrogen pipes and equipment should be protected from welding and grinding sparks by suitable protection devices such as welding/fire blankets. Such maintenance operations should be covered by a risk assessment, with specific attention to explosion and fire risks, in which all the measures necessary for ensuring safety are pre-defined.

Further information on electrical grounding and bonding to prevent ignition sources is provided in 10.1.4.

5.6 Mitigation of the escalation and/or impact of a fire or explosion originating from the fuelling installation

5.6.1 General

The following mitigations may reduce the effects of fires or explosions originating within the installation:

— flame or fire detection;

— equipment enclosures;

— access control measures (e.g., fences, walls, equipment enclosures);

— safety distances such as minimum distance between storages (see 5.8.1);

— explosion relief protection [see for example; API 521 Guide for pressure-relieving and depressurising systems].

5.6.2 Flame detection systems

Where identified by the hydrogen fuelling station risk assessment, means of detection of hydrogen fires should be provided to avoid escalation due to flame impingement on neighbouring equipment.

Infra-red, ultra-violet emission or thermal sensors may be used for hydrogen fire detection.

Means should also be provided to detect fires (e.g. smoke detectors) in equipment that have particular fire hazards (e.g. high current electrical equipment) if such fires can directly affect hydrogen storage systems.

5.6.3 Enclosures containing hydrogen systems

Enclosures containing hydrogen systems should be constructed of non-combustible materials.

Windows and doors should be in exterior walls and should be located so as to be readily accessible in case of emergency.

Requirements for the fire resistivity of the floor, walls, ceiling and any openings (doors, windows) should be defined by risk assessment.

If the floor, walls and ceiling are included to protect the hydrogen system from sources of fire, or to reduce safety distances from the hydrogen system to external objects due to a fire inside the enclosure, these should have a fire-resistance rating appropriate for the scenario and, where applicable, provide time for fire brigade intervention.

Requirements for over-pressure relief should be defined by risk assessment.

Where required, explosion venting should be provided in exterior walls or the roof only. Vents should consist of any one or any combination of the following:

— lightly fastened hatch covers;

— lightly fastened, outward-opening, swinging doors and/or suitable pressure relief windows in exterior walls;

— lightly fastened walls or roofs;

— walls of light material;

— continuously open vents in the exterior walls or roof of the enclosure.

Where applicable, snow loads should be considered.

The consequences of explosion relief e.g. over-pressure outside the opening, projectiles, movement of doors or hatches should be considered by risk assessment.

Requirements for the over-pressure resistance of the floor, walls, ceiling and any openings (doors, windows), where not intended for explosion relief, should be defined by risk assessment.

If the floor, walls and ceiling are included to reduce safety distances from the hydrogen system to external objects due to an explosion inside the enclosure, these should have an over-pressure capability appropriate for the scenario.

5.6.4 Emergency release of gas from hydrogen storage tanks under fire conditions

If hydrogen storage tanks may be exposed to fire conditions (from inside or outside the storage area or compartment) that could lead to rupture, thermally activated (non-reclosing) and/or manually activated valves should be provided to safely vent all the content of the hydrogen storage. Where such a valve needs manual activation, this should be possible from a safe location. In this case, the vent system should be designed accordingly, see 9.14.5.

NOTE National regulations can prohibit the use of manually activated valves.

5.7 Mitigation of the effect of an external fire/events on the fuelling station installation

5.7.1 General

Measures should be taken to minimize the effect of events that have potential to take place in the vicinity of the fuelling station. These measures may include the following:

— safety distances;

— lightning protection;

— fire barriers;

— vehicle impact protection;

— protection against spillage of flammable fluids from other sources;

— access control measures;

— protection against external events.

5.7.2 Layout

The layout of a hydrogen fuelling station should minimise the likelihood of damage from activities carried out on the fuelling station, or external to the fuelling station property.

This may include hazards from fires of stored fuel or other combustibles, including buildings, on or in the vicinity to the fuelling station, damage from impact of moving equipment / vehicles or environmental hazards such as falling trees.

Hydrogen installations should be kept free of debris and other flammable waste.

No flammable liquids should be able to accumulate under the hydrogen storage tanks.

5.7.3 Fire barrier recommendations

A fire barrier may be used as a mitigation option to reduce safety distances. A non-comprehensive list of example safety distances for which a fire barrier could be used is as follows:

— building of combustible material;

— flammable liquids above ground;

— stock of combustible material;

— flammable gas storage above ground;

— jet flames following ignition of hydrogen releases from the fuelling station;

— overpressure following delayed ignition of hydrogen releases from the fuelling station;

— pool fires following ignition of hydraulic oil releases.

If a fire barrier is used as a mitigation option, it should be made of suitable non-combustible materials and have a minimum fire resistance rating of 30 min, as measured according to ISO 834-1. Consideration should be taken for the overpressure effects generated around the barrier by an unignited or ignited release. Walls intended as mitigation against fires / over-pressure should have requirements defined by risk assessment.

Any walls intended to function as a fire barrier should not include means of overpressure relief.

When used in conjunction with an outdoor storage system, the fire barrier should not generate additional risks for operating personnel in case of foreseeable incidents, also see 5.7.6.

5.7.4 Mitigating against vehicular impact

Hydrogen storage and dispensers should not be located in a direct line of traffic, e.g. entrance / exit to station. Further details for the protection of dispensers from traffic are included in 9.10.1.

The station design should minimise the need for vehicle manoeuvres as far as is reasonably practical, in order to reduce the risk of an unsafe situation arising through, for example, the need for vehicle reversing. Vehicle movement on the station should be clearly identified by means of signs and markings. The fuelling station operator should conduct an impact assessment that takes into account the vehicle movements within the fuelling station.

Vehicular impact protection should be appropriate for the anticipated type and speed of vehicles in the vicinity of the hydrogen equipment.

NOTE Further guidance on examples of how to achieve this is included as Annex E.

5.7.5 Firefighting systems

The location and quantity of firefighting equipment should be determined depending on the size of the hydrogen fuelling station and in consultation with the local fire authorities.

Water should be made available in adequate volume and pressure for fire protection (firefighting and cooling of fire affected equipment) as determined in consultation with the local fire authorities.

For fire-fighting purposes, suitable fire-extinguishing appliances should be placed in readiness in the vicinity of hazardous areas. Details are to be co-ordinated with the local fire authorities.

Hydrogen fires should never be extinguished whilst allowing a release to persist. Where the source of hydrogen cannot be isolated from the point of the leak, hydrogen fires should be allowed to burn until the hydrogen fuel is completely consumed. Extinguishing a hydrogen fire before the hydrogen fuel is completely consumed could lead to an explosion in the event of a re-ignition of the hydrogen. The firefighting equipment should only be used to prevent the spread of a hydrogen fire, e.g. for cooling surrounding equipment or for cooling down the hydrogen storage to avoid bursting of the vessels. Water from the firefighting system should not be directed at or introduced into a hydrogen system vent stack.

5.7.6 Emergency principles and operations

Suitable roadways or other means of access for emergency equipment, such as fire department apparatus should be provided.

The installation should be designed so that authorised personnel have easy access at all times and have adequate means of escape in the case of emergency. Access should be prevented to all unauthorised persons. Emergency exits should be kept clear at all times.

Where fencing is provided to prevent access of unauthorised persons, and a passage way is necessary to allow unhindered access to and escape from the enclosure, the minimum clearance between the fence and hydrogen equipment should be 0,8 m. Timber or other readily combustible materials should not be used for fencing.

All gates should comply with the local fire and building codes. The gates should be wide enough to provide for easy access and exit of authorized personnel. Gates should not allow entry without a key or similar locking mechanism during normal operation. Gates should have access outwards and if equipped with a latch, should be equipped on the inside with fast release hardware that can be operated without a key.

Consideration should be given to the provision of an additional emergency exit where the size of fenced area or equipment location necessitates this. In cases where authorized personnel can be trapped inside compounds, there should be at least two separate outward opening exits, remote from each other, that are strategically placed in relation to the hazard considered.

Full emergency procedures should be established for each particular fuelling station in consultation with local fire authorities. Periodic drills should be carried out.

Where a risk remains that critical hydrogen equipment can be dangerously exposed to fire conditions, which may originate from non-hydrogen related equipment, despite all the means that can reasonably be taken at design level, the following safety systems should be considered:

— water sprinklers for cooling of equipment exposed to fire, see 5.7.5;

— means for the emergency venting of hydrogen storage tanks according to 5.6.4.

5.8 Safety distances

5.8.1 General

The safety distance is the distance to an acceptable risk level or the minimum risk-informed separation between a hazard source and an object (human, equipment, or environment) that will mitigate the effect of a likely foreseeable incident and prevent a minor incident from escalating into a larger incident. This includes effects from hazard sources beyond the boundaries of the fuelling station.

In various regulations and industrial practices, the term 'safety distance' often includes many types of distances, such as: protection distances, clearance distances, installation lay-out distances, distances to external risk sources, and distances within which restrictions apply (restriction distances).

NOTE 1 These safety distances are not intended to provide complete protection against catastrophic events. Protection against such events is fundamentally provided by other requirements or through an emergency response plan.

For standard equipment and events, safety distances may be prescribed by national regulations, see examples presented in Annex A, Table A.1 and/or may be determined through quantitative risk assessment of a generic design. For any given fuelling station, one may also conduct a quantitative risk assessment, which can be used to understand the risks and the effects of station-specific mitigations; the result of the analysis may result in a recalculation of the safety distance to result in station-specific safety distances. If the safety distance is too large, additional mitigation or prevention measures should be considered and the safety distances may be re-calculated using a quantitative analysis.

NOTE 2 The benefit of conducting quantitative analysis is that it generates safety distances that are specific to the fuelling station/site that is analysed.

The quantitative analysis is used to demonstrate that the fuelling station does not pose unacceptable risk to specific targets, taking into account the design and mitigation features of the actual installation. Acceptable quantitative techniques include Quantitative Risk Assessment (QRA) and consequence modelling (i.e., a QRA without quantification of the probability of scenarios). The analysis uses a combination of information and data regarding the fuelling station design and operation, validated physical models, and probabilistic models that meet the criteria discussed in the remainder of this clause. Use of a common, ISO standard toolkit is strongly suggested.

NOTE 3 An example of a safety distance toolkit is given in Annex A.

This Technical Specification recommends making a distinction between safety distances designed to protect against different hazards, and uses the following terms:

— Restriction distances

— Clearance distances

— Installation layout distances

— Protection distances

— External risk zone

5.8.2 Types of safety distances

5.8.2.1 Restriction distances

The restriction distance is the minimum distance from hydrogen equipment or area around where certain activities are restricted or subject to special precautions (e.g., no open ignition sources, like flames, hot works, electrical sparking, use of sparking tools, smoking, etc.).

NOTE This is addressed in 5.5.2. The remaining types of safety distances mitigate foreseen and unforeseen events other than those arising from activities restricted during normal operations.

5.8.2.2 Clearance distances

The clearance distance is the minimum distance between the fuelling station equipment and the vulnerable targets within the fuelling station site boundary. Here, the hydrogen installation is regarded to be the source, while the surrounding people /objects are considered to be the targets.

Examples of targets that may be exposed include personnel of the fuelling station, users of the fuelling station, and other facilities within the fuelling station like gasoline storage, gasoline dispensing and delivery facilities. Additional examples are listed in Table 3.

5.8.2.3 Installation layout distances

The installation lay-out distance is the minimum distance between the various equipment of the hydrogen installation required to prevent escalation to other equipment in case of an incident. Installation layout distances may be different combinations of hydrogen equipment.

Example of source-target pairs are dispenser and bulk storage; liquid or gaseous hydrogen storage and hydrogen venting. Additional targets are listed in Table 3.

5.8.2.4 Protection distances

The protection distance is to prevent damage to the hydrogen installation equipment from external hazards (e.g. fires) not accounted for in the installation layout distances.

NOTE In this case, the term external refers to both off-site events and also on-site events unrelated to the hydrogen equipment.

The protection distance prevents off-site and non-hydrogen-related events from escalating to the hydrogen equipment. Protection distances may be different for specific elements of the fuelling station equipment.

External sources of hazard often involve fires and collisions. Sources include presence of combustibles (e.g., gasoline storage area), on site vehicles using non-hydrogen parts of the fuelling station, and vehicles on nearby roads; additional example sources are provided in Table 2. Example targets are any equipment of the hydrogen fuelling station, including equipment listed in Table 3.

5.8.2.5 External risk zone

The external risk zone is the distance (or area) outside fuelling station which is to be protected from hazards caused by the fuelling station. Here, the fuelling station is the hazard source, while people and constructions offsite are regarded to be the target(s).

Example off-site targets include members of the public residing or working near the fuelling station; additional targets are listed in Table 3.

5.8.3 Examples of safety distances

Table 1 — Summary of types of safety distances

Characterization of safety distance	Purpose	Source	Target(s)
Restriction distances	Minimize risk in areas adjacent to hydrogen equipment	Fuelling station equipment	Any open area adjacent to hydrogen equipment
Clearance distance	Protect persons and objects within the fuelling station from hazards associated with the fuelling station	Equipment and objects within fuelling station	Persons and other facilities within the fuelling station
Installation lay-out distance	Prevent escalation of events within fuelling installation	Fuelling station equipment	Fuelling station equipment
Protection distance	Protect the fuelling station from damage due to any external hazards	Off-site facilities and on-site things (except for the fuelling station equipment)	Fuelling station equipment
External risk zone	Mitigate off-site risks from hazards associated with the Fuelling station	Fuelling station equipment	Surrounding people/ property outside of the fuelling station

Table 2 — Example sources for each type of safety distances.

Safety distance	**Example sources**
Clearance distance AND Installation lay-out distance AND External risk zone	Equipment of the fuelling station • Dispenser; • Compressor; • Liquid hydrogen storage; • Gaseous hydrogen storage.
Protection distance	Off-site or on-site: • Presence of other combustible liquids or gases (e.g., gasoline storage, LPG storage, pipelines containing flammable gases of liquids); • Buildings of combustible materials. On-site: • Vehicles using non-hydrogen parts of the fuelling stations. Off-site: • Vehicles on nearby roads; • Specific types of industrial buildings.
NOTE The information in this table is provided to facilitate identification of hazard sources that could be included in the model. It is not required to establish safety distances for any of the sources in the table. It is also possible to establish safety distances for sources not listed in this table.	

Table 3 — Example targets for each type of safety distance.

Safety distance	Example targets
Clearance distance	Persons: • Workers in the fuelling station (1st party); • Users of the fuelling station (clients, 2nd party) ; • Public and users of other facilities within the fuelling station (3rd party). Other facilities within the fuelling station: • Building such as convenience stores, carwash; • Gasoline storage; • Gasoline dispensing facilities; • Fuel delivery areas; • Building openings, air intakes.
Installation lay-out distance AND Protection distance	Equipment of the fuelling station: • Dispenser; • Compressor; • Liquid hydrogen storage; • Gaseous hydrogen storage; • Vent stack exits.
External risk zone	Persons: • Public (3rd party); • Places of public assembly. Property: • Lot lines; • Parking; • Houses; • Public buildings such as schools, hospitals; • High voltage lines.
NOTE The information in this table is provided to simplify target selection. It is not required to establish safety distances for any of the targets in the table. It is also possible to establish safety distances for targets not listed in the table.	

5.8.4 Safety distances relating to hydrogen vent stack outlets

The vent outlet location (height; distance to exposures) should be such that the limits for thermal radiation and over-pressure effects of ignited vented gas are not exceeded under any foreseeable venting situation considering unfavourable wind conditions. The safety distances for vented gas from liquid hydrogen systems should take into consideration the density of the gas.

The thermal radiation and overpressure effects of ignited vented gas (immediate or delayed ignition) should be considered for the anticipated vented gas.

Hydrogen concentration at windows, openings, air intakes and at locations where persons or personnel may be present should not exceed 4 % in air (100 % LFL), unless a lower concentration of hydrogen in air is required by national regulations or by risk assessment.

5.9 Protection measures for non-hydrogen hazards

5.9.1 General

In addition to the hazards related to hydrogen supply, storage and dispensing on the fuelling station site, other non-hydrogen hazards should be addressed. The risk assessment should identify measures taken to protect against the specific hazards listed below, where applicable:

— working at heights (see 9.3.2.3);

— asphyxiation (see 5.9.2);

— emergency egress routes out of enclosures or vaults (see 5.9.3);

— electrocution (see 10.1);

— moving machinery (see IEC 60204-1);

— anti-whip measures for hoses (see 5.9.5);

— noise (see 5.9.6).

5.9.2 Protection measures for asphyxiation hazard in an enclosure

When an equipment compartment is intended to be entered and contains or is connected to a source of hydrogen or inert gases that compartment should be evaluated for the potential of an oxygen deficient atmosphere during normal or off-normal conditions.

When the potential exists for an oxygen deficient atmosphere, procedures should be put in place to prevent this occurring whilst personnel are present in or entering into the compartment, or detection and notification appliances should be provided to warn personnel of an oxygen-deficient atmosphere.

Where fixed detections and notification appliances are used, notification appliances should produce a distinctive audible and visual alarm and be located outside the entrance to all locations that where the oxygen-deficient condition could exist.

Hydrogen piping and equipment should be isolated, depressurized and made safe prior to replacement of components. Vent gas and purge gas should be exhausted outside of the hydrogen compartment before and after replacement or service work requiring depressurization

5.9.3 Protection measures for emergency egress from enclosed spaces

Exterior access doors should be secured against unauthorized entry. Where access doors do not need to be secured to protect workers against hazards, for example, live electrics, see IEC 60204-1, doors do not need to be secured if a secured perimeter fence or wall is provided to prevent unauthorized entry.

Locks or latches on emergency doors should not require the use of a key, a tool for the operation from the egress side.

Enclosed spaces e.g. equipment containers or vaults (see 9.3.2.2), should be provided with a personnel access way with a minimum width of 0,8 m and ensure a permanent escape route. The travel distance from points of maintenance inside an enclosed space to an emergency egress point should not exceed 6 m, otherwise multiple means of egress should be provided.

NOTE Egress recommendations are not applicable when all operation and maintenance-related work is performed from the exterior of the enclosure.

5.9.4 Protection measures from environmental conditions

Equipment enclosures should be designed and tested for the intended installation environment, as defined in IEC 60529. In function of the installation environment, the appropriate rating should be chosen.

NOTE 1 Components and equipment individually protected to the levels recommended by this document (or better) do not need to be enclosed, and subsequently enclosures not intended to provide weather protection do not need to meet this IP rating.

NOTE 2 IEC 60529 does not directly address ice, sleet, snow, saline atmosphere or other conditions that can be encountered in outdoor applications. A “W” in the third character of the IP code indicates “weather conditions”, however no specific requirements are provided. IEC 60068-1 contains additional guidance on environmental testing.

5.9.5 Protection measures for hose whip

For working pressures in excess of 4 MPa, hoses assembled should be provided with a suitable restraining cable, sleeve or device, properly fitted to an anchor point on each end of the hose to restrain the hose in the event of a hose assembly failure (see ISO 14113).

Other anti-whip measures, for example, identifying failure of a hose assembly through the control system and isolating the supply of gas, see 8.2.3.5, may be used in place of restraining devices where appropriate.

5.9.6 Protection measures for noise

Sound pressure level and sound power level under normal operating conditions should not exceed relevant local limitations. Events such as the opening of a relief valve, or break-away event etc are not considered normal operation.

6 Process control and safety systems

6.1 General

This clause defines the minimum recommendations for the functional safety of the control and safety system.

The hydrogen fuelling station should be equipped with a control system that enables automated operation of the station within the manufacturer’s specified limits. Control systems should maintain operating conditions within safe limits, carrying out a process shutdown as appropriate when these limits are reached and respond to any abnormal states by automatically activating mitigating measures as part of an emergency shutdown.

The individual risk assessment will dictate what to do when there is a system fault on the process control or safety system.

Where the manufacturer’s risk assessment requires a response to abnormal states (faults) with an increased reliability to that achievable from the control system, the fuelling station should be equipped with an additional safety system or layer of protection. IEC 61508 and 61511 could be used for specification, design, testing, operation and maintenance of such a safety system.

Electrical control systems, components of hydrogen fuelling stations, and devices determined by the manufacturer to be safety related control systems, should comply with the requirements of IEC 60204-1.

The safety system could be composed of several safety functions activated manually or automatically.

The configurations of process control and safety systems should be documented.

There should be restrictions regarding admittance to the control and safety systems by using password protection. Where specific operations require safety systems to be non-functional, a risk assessment should be executed and documented before the start of the operation.

As part of the safety system an alarm system can be implemented. The station should fall to a safe state by itself, not relying on the alarm system. The alarm system should only be used to give any user or operator notification about the fuelling station.

NOTE 1 See especially Control circuits and control functions, and Operator interface and machine-mounted control devices of IEC 60204-1, Clauses 9 and 10.

NOTE 2 IEC 60204-1 includes essential requirements for safety related controls that are often overlooked including:

— stop categories;

— emergency operations (emergency stop, etc.);

— protective interlocks;

— control function in the event of failure – including references to:

— IEC 62061;

— ISO 13849-1;

— ISO 13849-2;

— protection against maloperation due to earth faults, voltage interruptions and loss of circuit continuity.

All elements which remain under pressure after isolation following a process control or safety system shutdown, or from loss of the electrical power supply, should be provided with clearly identified vent systems, and details drawing attention to the necessity of depressurizing those elements before setting or performing maintenance activity on the equipment unit should be included in the equipment manual (see 12.10).

6.2 Emergency shutdown functionality

The extent and response of the emergency shutdown function, instigated through the control or safety system, whether automatically or by manual actuation of an emergency stop device, should be determined according to the fuelling station risk assessment, see 5.1. The emergency shutdown function should be so designed that, after actuation, hazardous movements and operations of the fuelling station are stopped in an appropriate manner, without creating additional hazards and without requiring any further intervention by any person, and should comply with ISO 13850 or IEC 60204-1. Where appropriate, activation of emergency isolation valves shutting off the hydrogen supply should be utilized.

The control or safety system performing the emergency shutdown should override all other functions and operations that could prevent the emergency shutdown actions. Emergency safeguarding should remain effective for all operating modes.

Provision of an overall (or global) emergency shutdown function that carries out a shutdown of the complete hydrogen system should be considered, in addition to hazards where a localised shutdown may be more appropriate.

Further detail for the emergency shutdown function specific to the dispenser is provided in 9.10.3.3.

Control circuits should be arranged so that, when an emergency shutdown is activated, hydrogen supply and storage systems that are shut down or isolated as appropriate, should remain shut down until proper maintenance checks are performed and the system is manually reset. A manual operation is required for the dispenser to resume operation.

Control and monitoring systems that can operate safely in the hazardous situation may be left energized to provide system information.

In the event of an emergency, the emergency shutdown also should shut off the liquid supply and power to the liquid hydrogen transfer equipment necessary for producing gaseous hydrogen from liquid hydrogen. In the event of an emergency shutdown, the design should allow for pressure relief within any closed system

Where the manufacturer's safety case permits or requires equipment, such as the hydrogen gas detection system and ventilation systems, to remain energised in such an event, this should be suitable for use in classified areas according to 10.2.2 or 10.2.3.

6.3 Manually actuated emergency stop devices

The fuelling station should operate in conjunction with readily accessible manually actuated emergency stop devices, see IEC 60204-1, positioned in appropriate locations with consideration given to the hazardous areas initially generated by foreseeable incidents. Emergency stop devices should be located in the vicinity of hydrogen dispensers, and at other locations where the initiation of an emergency stop may be required, such as inside the fuelling station office, where applicable, and in compressor and storage areas.

Emergency stop devices should be clearly identified with a permanently affixed legible sign. An emergency stop device located at the dispenser, or on specific pieces of equipment, may have a different functionality to an emergency stop device for the entire hydrogen system, or for the entire fuelling station. Where the functionality of emergency stop devices differ, this should be clearly defined.

Where emergency stop devices are located in the office of an integrated fuelling station, the function of these actuators being specific to the complete hydrogen system only, or to include other activities on the fuelling station, should be determined by risk assessment.

An emergency stop device should be provided in the vicinity of the dispenser, but sufficiently separated from the dispensing area such that it can be safely actuated under fault conditions without entering a potentially hazardous area.

Where hydrogen is used in enclosed, or indoor areas, in addition to any emergency stop device(s) located indoors, devices should also be provided outdoors, for example, close to the point of egress.

The possibility of inadvertent or malicious activation of emergency stop devices should be considered when locating and labelling the emergency stop device in order to avoid "false alarms" and unnecessary emergency responses.

6.4 Remote system control

A hydrogen fuelling station may be provided with the following capabilities:

— remote monitoring / data transmission

— remote operation, for instance giving permission for fuelling, or restarting the station after a fault

— remote control code modifications (software update, flashing etc.).

Where the capability for the manufacturer, or the operator, to restart the station after a fault, or modify the control logic remotely is provided, the measures that should be taken to ensure this is carried out safely should be defined, including consideration of the need for presence of maintenance staff on-site.

These control code modifications capabilities could include:

— modify the control parameters remotely;

— certify an upgrade to the remote monitoring system;

— certify a parameter change;

— change parameters remotely;

— upload parameters;

— qualify the operation;

— undo/reverse all changes;

— test and backup documentation.

7 Hydrogen supply safety and operation

7.1 On site generation

7.1.1 Hydrogen generators using water electrolysis process

Hydrogen generators using water electrolysis process should meet the requirements of ISO 22734-1 or national/regional standards.

7.1.2 Hydrogen generators using fuel processing technologies

Hydrogen generators using fuel processing technologies, including ancillary hydrocarbon storage and pipework, should meet the requirements of ISO 16110-1 and references therein.

Storage of hydrocarbon fuels should be sited to minimise risk to personnel, local population and property. Consideration should be given to the location of any potentially hazardous processes in the vicinity, which could jeopardise the integrity of the hydrocarbon and hydrogen storage installation.

7.2 Hydrogen delivery

7.2.1 Gaseous hydrogen supply by tube trailers and multiple element gas containers (MEGC)

Gaseous hydrogen can be delivered on site by tube trailers or MEGC. Trailers can either deliver to storage vessels at the fuelling station site or remain at the site and be replaced when the inventory of the hydrogen product in the trailer is low. Gaseous hydrogen may also be delivered on site in transportable gas storage devices containing hydrogen absorbed in a metal hydride storage system. In such cases, ISO 16111 should be used to ensure safety of the metal hydride storage system.

The tube trailer or MEGC stationing area should be level and support the front and rear ends of the tube trailer or MEGC in a designated area or unloading bay. The area should be kept free of debris and combustible materials.

A bump stop or equivalent should indicate normal tube trailer or MEGC position in the unloading bay when a driver needs to reverse into the bay.

Hydrogen tube trailers or MEGCs should not be stationed outside of the designated trailer unloading bays.

The location of the transfer panel or pressure reducing station should be accessible only to authorized persons.

Means to ground tube trailers and MEGCs prior to flexible hose connection should be provided.

A designated temporary tube trailer or MEGC parking location should be provided for carrying out tube trailer or MEGC exchange without interfering with fuelling operations, unless the fuelling activity is fully suspended during the tube trailer or MEGC exchange operation. The foundation under a tube trailer or MEGC remaining on site should be made of reinforced concrete, or any other suitable non-combustible material.

A risk assessment of the hydrogen delivery process should be carried out, see 5.2. Activities other than those directly related to the hydrogen tube trailer and/or MEGC operation should not be permitted in the hydrogen storage area.

7.2.2 Liquid hydrogen supply

7.2.2.1 Liquid hydrogen storage layout and design features

The liquid hydrogen storage tanks should comply with ISO 21009-1 or be designed in accordance with a commonly used national/regional standard.

It is preferable that wherever possible, liquid hydrogen storage and related equipment is located above ground in the open air in a well ventilated area to minimize the consequence of an accidental leakage. If any protective structures are used to reduce the safety distances, they should be designed to avoid any unintentional hydrogen confinement.

However, underground installation, e. g. in a vault, may be needed and used when it is beneficial to keep above ground areas free of equipment, such as may be the case for hydrogen vehicle fuelling stations. For this layout additional measures may have to be taken according to the risk assessment.

Connections to bulk storage systems and equipment controls necessary for filling purposes should be located in close proximity to each other and in such a way that the storage tank fill control valves and delivery vehicle controls are accessible from the delivery vehicle operator's position.

A risk assessment of the hydrogen delivery process should be carried out, see 5.2.

7.2.2.2 Liquid hydrogen transfer area

The liquid hydrogen transfer area should be designated as a "NO PARKING" area.

A concrete or any other suitable non-combustible material hard standing area should be located adjacent to the fill coupling of the liquid hydrogen storage tank.

The liquid hydrogen transfer area should be clearly defined and transfer of liquid should only take place within the fuelling station premises. A risk assessment of the hydrogen delivery process should be carried out, see 5.2.

Means to ground liquid hydrogen delivery vehicles prior to flexible hose connection should be provided.

The connection point in the transfer area should be protected sufficiently against a vehicle crash from either the delivery vehicle, any traffic on the filling station or other traffic (e.g. vehicles from roads not part of the fuelling station).

7.2.2.3 Tank foundation and supports

Where liquid hydrogen storage tanks are required to be elevated, the tank supports should be non-combustible structures, capable of withstanding damage by cryogenic liquid spillage. Liquid spillage should be diverted from the support structure of the storage tank by a slope or other means.

The tank foundation should be designed to withstand the weight of the liquid hydrogen storage tank, its contents and other possible loads applied by wind, snow, seismic, etc.

The foundation on which the liquid hydrogen storage tank is installed should be made of concrete or any other suitable non-combustible material.

National regulations may need the design and implementation of the foundation to be reviewed and/or inspected by a third party prior operation.

7.2.2.4 Liquid hydrogen delivery lines

Flexible hoses used for liquid hydrogen delivery should comply with ISO 21012.

Liquid hydrogen delivery lines should have a device, such as a non-return valve or an emergency isolating valve, preventing backflow from the ground (bulk) storage tank in case of hose rupture. Means to ensure that emergency isolation valves can be actuated in case of leaks in the hydrogen delivery lines should be provided.

The location of safety shut off valves in liquid hydrogen service should be such that their actuators do not risk being blocked by accumulation of ice in case of a foreseeable hydrogen leak or release.

Means to immobilize the trailer while the fuelling hose is connected should be provided.

7.2.2.5 Pressure relief devices

When required, the liquid hydrogen systems and equipment should be protected from over-pressure e.g. by use of one or more PSD (pressure safety device), or by other appropriate means. A PSD can be of the self-destructive type, such as rupture disks and diaphragms, or of the resealable type, such as PSV (pressure safety valve) spring-loaded pressure relief valves.

PSVs should meet the requirements of ISO 21013-1 or an equivalent standard recognized in local regulation.

Burst disc safety devices should meet the requirements of ISO 21013-2 or an equivalent standard recognized in local regulations.

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

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

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

If a three-way diverter valve is installed to accommodate two PSVs operating, either simultaneously or alternatively, the flow area of the three-way valve should be such that the liquid hydrogen storage tank is adequately protected regardless of the position of the diverter valve.

The three-way diverter valve should be provided with a position indicator, if appropriate, showing which PSV is “on line”.

Consideration should also be given in the design of the installation to facilitate the periodic testing of the pressure relief devices.

7.2.2.6 Cold hydrogen vents

All vents, including those of pressure relief devices and purge valves, should be connected to a vent stack, refer to 9.14.4.

The vent stacks should be dedicated to the liquid hydrogen installation and not be connected to other vent stacks to avoid any back feed into the hydrogen vent stacks.

7.2.2.7 Purging

Cold sections of liquid hydrogen installations and transfer hoses should be purged with warm hydrogen or helium prior to being purged with nitrogen.

Following installation or repair work, cold sections of liquid hydrogen installations should be purged with helium or warm hydrogen. If nitrogen is used instead of helium to remove air in cryogenic sections, the nitrogen should then be purged with helium or warm hydrogen prior to cool down with cold hydrogen for start-up to prevent nitrogen solidification.

7.3 Pipeline

The interface between the hydrogen pipeline and the fuelling station may include:

— isolation for emergency and/or maintenance;

— means for safe relief of pressure;

— means for nitrogen purging;

— pressure and/or flow regulation;

— metering;

— filtration.

NOTE The interface between the hydrogen pipeline and the fuelling station is typically located within the fuelling station boundary.

8 Hydrogen dispensing

8.1 Dispensing description

The Figure 4 below describes an example of the key components of the fuelling station dispenser including the fuel cell electric vehicle compressed hydrogen storage systems (CHSS) with sensors as well as pressure relief device(s). The CHSS has a thermally activated pressure relief device(s) to protect against overpressure due to a fire. On the station side, there is an automated dispensing control system (e.g. through a PLC) for performing the fuelling (using an acceptable fuelling protocol), as well as fault detection and management procedures. The station also has mechanically-independent pressure relief device(s) to protect against over pressurization of the dispenser and the vehicle.

Fuelling should be metered in the station and the hydrogen temperature and pressure should be monitored and controlled by the dispenser. The ambient temperature is monitored as well at the station. A fuelling hose assembly on the station dispenser should contain a breakaway, hose and nozzle. The vehicle CHSS can be fuelled after connecting the station dispenser to the vehicle receptacle and after the start-up procedure from the dispenser. The station fuelling nozzle may contain a communications receiver and the vehicle may contain a communications transmitter (such as SAE J2799).

The hydrogen fuelling station should prevent the allowable limits of temperature, pressure and state of charge (SOC) for the vehicle CHSS system from being exceeded.

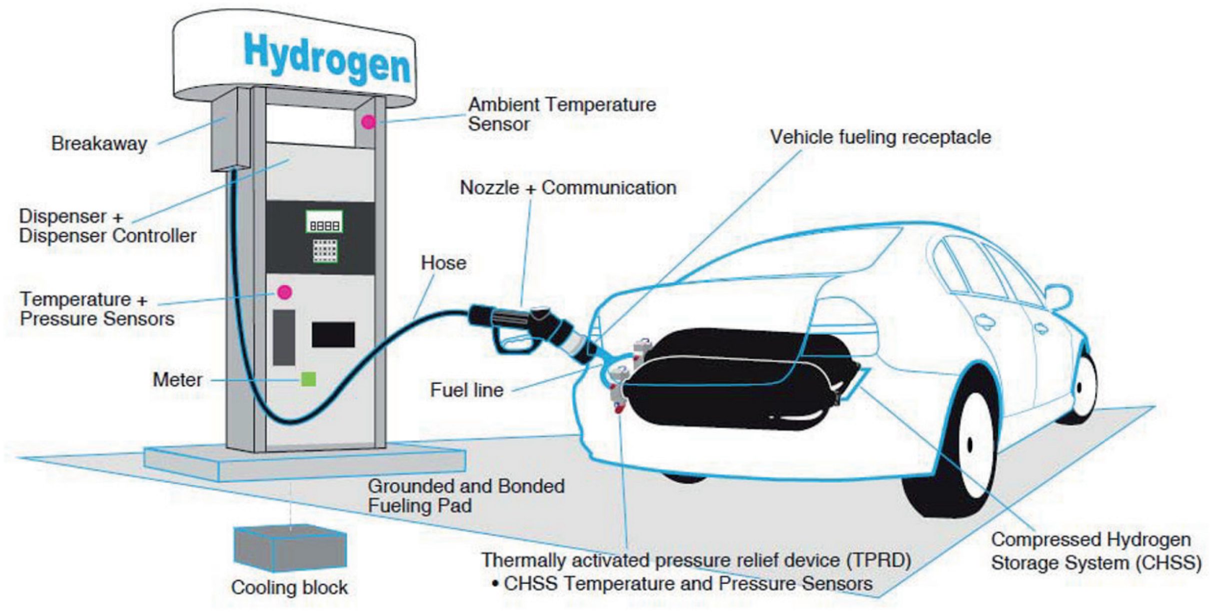


Figure 4 — Example of the fuelling station dispenser key components including the vehicle CHSS

8.1.1 Dispenser components

The station manufacturer should ensure the dispenser fuelling hardware is rated properly for the application (temperature and pressure). For example, proper nozzles and associated components are to be fitted according to the appropriate ISO 17268 "H" pressure class rating according to application (e.g. H70 for 70 MPa NWP hydrogen fuelling.) See 9.10.3.2, "Rated operating conditions."

8.1.2 Dispenser sensors location

The ambient station temperature, and the temperature, pressure and mass flow rate of the hydrogen fuelling should be monitored. The station dispenser controller uses this data for the control system to manage the fuelling process.

The hydrogen temperature and pressure sensors measuring the station dispenser fuel delivery conditions should be located upstream of and as close as possible to the dispenser hose breakaway. SAE J2601 states that the piping length between sensors and hose breakaway should be no greater than 1 m.

The dispenser hydrogen pressure sensor, measuring the fuel delivery pressure, should be located upstream of the dispenser hose breakaway coupling, ensuring no components that could restrict the hydrogen flow to the vehicle (leading to a pressure drop greater than that specified in 8.2.2.4.5) are located between the pressure sensor and the breakaway.

The ambient temperature sensor should be placed in a location in order to give an accurate reading and should not be located in the direct sunlight.

8.1.3 Ambient temperature range of fuelling

Dispensers should only fuel when the ambient temperature is greater than or equal to -40 °C and less than or equal to 50 °C.

8.2 Hydrogen FCEV fuelling

8.2.1 Reference fuelling limits of FCEV vehicles

8.2.1.1 Global technical regulation key limits

A complete set of hydrogen limits and extreme validation testing for the vehicle CHSS is found in the GTR #13. See Figure 1 in the GTR to see the scope of a “typical compressed hydrogen storage system.” The following provides key limits for the design and certification of the CHSS according to the excerpts GTR #13:

— the minimum number of full pressure hydraulic qualification test cycles for hydrogen storage systems is set at 5500 (GTR Clause 58.d).

— assurance of capability to sustain multiple occurrences of over pressurization due to fuelling station failure is provided by the CHSS requirement to demonstrate absence of leak in 10 exposures to 150 per cent NWP fuelling followed by long-term leak-free parking and subsequent fuelling/de-fuelling. (GTR Clause 61.f)

— the CHSS component complies with the external leakage test at the appropriate maximum material temperature (-40 °C to +85 °C) at the completion of the high temperature cycles (GTR Clause 7.4.4.3.5).

Hydrogen stations should not fuel vehicles which cannot operate in the full range of the limits above (and according to the GTR #13) unless the safety of such a fuelling can be demonstrated by risk assessment to be appropriate.

NOTE Compressed hydrogen storage vessel materials are qualified to 85 °C (material temperature) in the GTR durability test protocol. Since the bulk gas temperature is typically 5 °C -10 °C higher than the material temperature, there is an embedded 5 °C margin (Reference: SAE 2011-01-1342) within the fuelling limit to manage measurement errors and the transient thermal conditions during fuelling.

8.2.2 Fuelling process control

8.2.2.1 General recommendations for the fuelling protocol

Hydrogen dispensers should use a fuelling protocol such as SAE J2601 to ensure that the fuelling is conducted within the fuelling protocol process limits for vehicles compressed hydrogen storage systems as defined in 8.2.2.2 over the full range of ambient temperature defined in 8.1.3.

Any fuelling protocol other than SAE J2601 should be approved by each manufacturer of the vehicles prior to fuelling at the station. The fuelling station operator should take measures necessary to prevent the fuelling of vehicles where this condition is not met.

The dispenser may either conduct the fill using communication with the vehicle as part of the fuelling process or conduct the fuelling protocol without communications with the vehicle. The SAE J2601 fuelling protocol, for example, has provisions for both communication and non-communications fills. The vehicle IrDA communications system may use the SAE J2799 protocol to transmit the measured temperature and pressure of the compressed hydrogen storage system on the vehicle to the hydrogen dispenser. If other communications protocols are used, they should be validated to confirm compatibility and robustness.

8.2.2.2 Fuelling protocol process limits

The fuelling station dispenser may be designed with separate nozzles to fuel vehicles to 35 MPa and/ or 70 MPa nominal working pressures. The station manufacturer should ensure the proper nozzles and associated components are fitted according to the appropriate pressure and that the pressure limits stay within the values in this clause.

The fuelling protocol should consider the full range of possible ambient temperature and vehicle operating conditions when establishing the fill rates to ensure that the storage system on the vehicle does not inadvertently experience an over-fill or over-temperature condition.

The fuelling protocol should adjust fuelling rates and targets based on measured ambient and process conditions such as hydrogen gas temperature, pressure, and the temperature and pressure of the storage system on the vehicle (if communicated) to ensure that the process limits in 8.2.2.4.1 are maintained for the vehicle. If these conditions cannot be maintained within the limits, the fuelling should cease.

During filling the station dispenser should terminate the fuelling within 5 seconds if any of the following fuelling protocol limits are exceeded:

— ambient temperature range between -40 °C and +50 °C;

— maximum operating pressure (MOP) should be less than or equal to 125 % of the nominal working pressure. For example for 35 MPa the MOP 43,75 MPa and for 70 MPa it is 87,5 MPa; See 8.2.3.3 for over-pressure protection measures if a fault occurs;

— dispensers should not fuel a vehicle which arrives with a pressure lower than 0,5 MPa;

— minimum gas temperature should be greater than or equal to −40 °C;

— maximum bulk CHSS gas temperature should be less than 85 °C;

— maximum vehicle state of charge should be 100 % of the nominal state of charge;

— maximum fuel flow rate should be no greater than 60 g/s for light duty vehicles;

— The maximum hydrogen mass allowed to be transferred to the vehicle prior to the start of fuelling should be 200 g.

The fuelling protocol should be appropriate for the vehicle tank capacity (e.g. 2 kg to 10 kg for 70 MPa SAE J2601)

For example, SAE J2601 includes average pressure ramp rates and target pressures for both H35 and H70 to fill to 35 MPa and 70 MPa, respectively. This standard covers fuelling of light duty vehicles with 2 kg to 10 kg hydrogen storage. Fuelling should cease when the target pressure or 100 % SOC has been achieved.

8.2.2.3 Fuelling protocol performance targets

The hydrogen fuelling protocol should be designed to fuel vehicles within performance targets, such as those specified in SAE J2601, without exceeding protocol process limits of 8.2.2.4.1. Hydrogen fuelling should be validated at station commissioning using a Hydrogen Station Test Apparatus (HSTA), such as found in Annex B.

An example fuelling protocol performance target is to achieve a 3 min fuelling with 95 % to 100% resulting CHSS SOC (with communications) without exceeding the fuelling limits (reference 8.2.2.2). However, it is understood that “intended non-fuelling time” such as bank switching between cylinders at the dispenser and leak checks can add to the overall fuelling time.

SAE J2601 gives a ramp rate which indicates an approximate fuelling time with a high resulting CHSS state of charge (SOC). The fuelling pressure ramp up to the target SOC should be within the pressure window such as given by the look up tables in SAE J2601 fuelling protocol specification.

8.2.2.4 SAE J2601 standard fuelling protocol and SAE J2799 communications

The SAE J2601 standard assumes that a station will perform fuelling into the vehicle after successful vehicle connection and completion of initial checks. The fuelling station is responsible for controlling the fuelling process within the operating boundaries.

Variables that affect the fuelling process include, but are not limited to: Ambient Temperature; Dispenser Pressure Class and Fuel Delivery Temperature; CHSS Size and Specification, Starting Temperature and Pressure; and Dispenser to CHSS Pressure Drop and Heat Transfer. An important factor in the performance of hydrogen fuelling is the station's dispensing equipment cooling capability and the resultant fuel delivery temperature "T" rating.

SAE J2601 includes protocols for two pressure classes (35 MPa and 70 MPa), three station fuel delivery temperatures (-40 °C, -30 °C, -20 °C) and compressed hydrogen storage system sizes from 49,7 lto 248,6 l. A T40 station dispenser, for example, has a fuel delivery temperature between -40 °C and -33 °C.

The fuelling process may connect a vehicle to the fuelling station's communication system, such as SAE J2799. If the station has communication capabilities, it should terminate the fuelling within 5 seconds upon receiving an abort signal (such as FC=Abort command defined in SAE J2799).This communication may not necessitate an emergency shutdown according to the requirements of Clause 6.

The SAE J2601 table based fuelling approach uses the station fuel delivery category, ambient temperature, vehicle capacity category, and vehicle initial pressure to select appropriate fuelling parameters. The fuelling stops when the target pressure, found in the tables is reached or based on SOC (95%-100%) if using communications. The Pressure Corridor (such as SAE J2601) gives the fuelling tolerances for the average pressure ramp rate and fuel temperature window gives the tolerances for the gas temperature at the station dispenser.

The station selects the appropriate look-up table based on fuel delivery temperature, Compressed Hydrogen Storage System (CHSS) capacity category, and the absence or presence of a communications signal from the vehicle. Once the proper table is selected, the station determines the specific fuelling event parameters of Average Pressure Ramp Rate (APRR) and target pressure, based on ambient temperature and vehicle initial pressure,

Below (Table 4) is a reference for the tables based fuelling process limits according to SAE J2601. A complete list can be found in Annex B.3.4. During filling the station dispenser should terminate the fuelling within 5 seconds if any of the following table based fuelling protocol limits are exceeded.

Table 4 — Table based fuelling protocol requirements (SAE J2601)

SAE J2601 table based fuelling protocol requirement	Pressure and temperature limits
Fuel delivery temperature at start-up	Dispenser fuel temperature (Tfuel) category min ≤ Tfuel within 30 s after the start of fuelling
Fuel delivery temperature tolerance	Tfuel category min < Tfuel ≤Tfuel category max
CHSS capacity	85 % CHSS Cap Actual ≤ CHSS Cap Measured ≤ 115 % CHSS Cap Actual
Initial CHSS pressure (at the beginning of fuelling)	0,5 MPa < Pvehicle < NWP Station
Upper station pressure tolerances	Pstation ≤ P0 + (APRRtarget) (tfuelling) + ΔPupper, where ΔPupper = 7,0 MPa
Lower station pressure tolerances	Pstation ≥ P0 + Max [((APRRtarget) (tfuelling) – ΔPlower), 0], where ΔPlower = 2,5 MPa
Cycle control	Fuel flow stoppage (below 0,6 g/s) may not happen more than 10 times during a fuelling event
Non-communication end of fuelling	Fuelling stops when Pstation ≥ Ptarget
Communication end of fuelling	Fuelling stops when Pstation ≥ Ptarget, or 95% ≤ SOCvehicle ≤ 100 %. Note, the communications fuelling tables which have a target pressure take precedence over the SOC calculation to ensure that the CHSS stays within its operational boundaries.

8.2.3 Manual control of dispensing

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

8.2.4 Pressure integrity check (leak check)

Control systems on fuelling stations should be designed to verify the integrity of the fuel hose, breakaway, nozzle and connection to the vehicle before fuelling. Integrity should be checked while the vehicle is connected. The integrity test should detect significant degradation of pressure indicating a leak, and shut down in the event of detection.

The inclusion of additional high pressure integrity checks during and/or after fuelling, and/or in between fuelling events should be used as an option until such time the dispenser components have a demonstrated history of success.

If the pressure integrity check is not successful, an emergency shutdown should be executed according to 8.2.3.2.

8.2.5 Metering

If required, the dispenser should feature a metering device connected to a readout giving the quantity of hydrogen dispensed for each vehicle fuelling operation (in kilograms, to accuracy as required by national regulations if applicable).

8.2.6 Maximum flow rate and pressure drop

The maximum hydrogen fuel flow rate should be no greater than 60 g/s for light duty vehicles.

The pressure drop between the dispenser pressure sensor monitoring the vehicle pressure and the nozzle should not exceed 15 MPa at reference flow conditions as defined by SAE J2601.

8.2.7 Flow control and isolation

The dispenser isolation valves in 9.10.3.3 are opened to perform the dispensing operation but are not to be used to control the hydrogen flow during the dispensing. The dispenser isolation valves should be closed when dispensing is complete.

A separate control valve system should be used for controlling the flow in accordance with the intended fuelling protocol. The dispenser control should suspend or stop the fuelling process by closing the isolation valves if any of the limits defined in 8.2.2.1 are reached.

See 8.2.3 for safety-critical actions that should be performed.

8.3 Dispenser safety devices

8.3.1 General considerations

The dispensing control system should be capable, at any point in time during the fuelling process, to detect a deviation that could be indicative of a fault that leads to a hazardous condition and execute countermeasures that will mitigate the hazard or stop the fuelling. See Clause 6 for guidance in the design and maintenance of process control and safety systems.

The required reliability, or safety integrity level (SIL), as defined in IEC 61508, IEC 61511, IEC 62308, IEC 31010, ISO 13849-1 and/or ISO 12100 of safety measures intended to prevent a hazardous situation in case of a failure of the dispensing control system hardware or software with regards to pressure and gas temperature should be determined through risk assessment.

Faults and associated hazards should be considered as part of the risk assessment according to 5.2. As a minimum, countermeasures should be provided to ensure that no single faults, including items identified in 8.2.2.3 through 8.2.2.4.4, result in a hazardous situation in the dispensing area. If the fuelling ramp rate is determined from the result of a measurement by the fuelling station dispenser or information communicated to the fuelling station, then this function should be shown to be sufficiently reliable to effectively avoid an unacceptable risk of overfill, over-temperature or over-pressure in the vehicle tank.

8.3.2 Dispensing emergency shutdown

The dispenser should operate in conjunction with an emergency shutdown function. Refer to 6.2

The emergency shutdown function should be operational at all times and override all other functions and operations in all operating modes of the dispenser.

Activation of the emergency shutdown should cut off the flow of hydrogen gas to the dispenser and vehicle by closing the automatic isolation valves defined in 9.10.3.3.

Other emergency shutdown functions that may need to be considered in the risk assessment include:

— vent any remaining gas in the dispenser lines to a safe location;

— shut down the upstream compression systems where these compress hydrogen directly to the dispenser;

— removal of power to non-classified electrics in the vicinity of the dispenser.

Other emergency stop functions may need to be considered to leave the dispenser in a safe state.

8.3.3 Over-pressure protection

A means should be provided within the dispenser control system to detect a failure of the dispenser pressure sensor or pressure control function, and, if necessary, execute an emergency shutdown according to 8.2.3.2. In order to not interfere with normal control action according to 8.2.1, the set point for this action may be set as high as the Maximum Operating Pressure (MOP), equivalent to 125 % NWP, if there are appropriate station dispenser controls in place to reliably prevent this value from being exceeded.

For example, for 70 MPa, the pressure should stop at the target pressure for fuelling during normal fuelling operation, which under certain circumstances can be as high as 87,5 MPa.

Additionally, a pressure safety valve (PSV), or equivalent, on the dispensing line or hydrogen supply to dispenser should be used to protect against over-pressurization of the components and piping in the dispensing system (see 9.10.3.1) as well according to 8.2.1.

In order to avoid over pressuring of components, the set point for a dispenser PSV should be set no higher than 138 % of nominal working pressure (NWP), if there is enough station reliability to ensure 125 % NWP will not be exceeded above the assumptions in 8.2.1. For example, for 70 MPa, the PSV may be set as high as 96,6 MPa. The dispenser PSV should prevent the pressure from rising above 150 % of the NWP.

If the dispenser control cannot reliably prevent pressure excursions above 125 % NWP (as defined above), then the set point of the dispenser PSV may have to be lowered to adequately protect the vehicle CHSS according to 7.2.1 or additional measures may be required.

Additionally if components in the dispensing system are rated lower than values defined in 9.10.3, then the set point of the PSV should be lowered to protect the lowest rated component in the dispensing system.

In either case, if the PSV set-point is lowered below 138 % NWP, then the maximum fill pressure should be lowered below the MOP accordingly.

8.3.4 Dispenser temperature control faults

When ambient temperature is measured for the purpose of establishing the vehicle pressurization rate or fuelling target, the dispensing system should be equipped with a means to confirm that the ambient temperature is correct.

If pre-cooling of the dispensed hydrogen is used, the dispensing system should be equipped with a means to confirm that the pre-cooled fuel temperature is correct and that the control meets the limits of the fuelling protocol, such according to SAE J2601.

If the fuelling protocol, such as SAE J2601, uses communication of the tank temperature on the vehicle and experiences a failure of the communication, the protocol should execute a non-communication fuelling that is allowed by the protocol, such as SAE J2601.

8.3.5 Limitation of hydrogen released in case of fuelling line break

A suitable means should be provided upstream of the fuelling hose assembly to detect a potentially hazardous leak (e.g. failure of a breakaway to close, hose leak, etc.) and limit the release of hydrogen. The minimum leak flow and maximum allowable reaction time that is required for such means to actuate should be determined.

Examples of possible means to detect the leak and thereby meet this requirement are listed below. One or more means may be required to achieve the required level of safety based on the specific system being protected. Examples of possible means to detect the leak are:

— detection of a dispensing pressure that is below the level targeted by the fuelling protocol and activation of the emergency shutdown according to 8.2.3.2.

— detection of low dispensing pressure and activation of the emergency shutdown according to 8.2.3.2.

— detection of an unexplained reduction in dispensing pressure and activation of emergency shutdown according to 8.2.3.2.

— detection of a higher-than-expected dispensing flow and activation of the emergency shutdown according to 8.2.3.2.

— detection of a higher-than-expected dispensing flow and closure by an excess flow valve.

8.3.6 Process control failure

For the situation where programmable process controllers are used to control the fuelling protocol, the possibility of a hardware or software failure that would cause the controller to “lock up” and cease execution should be addressed. A means should be provided to detect that the controller has failed and, if necessary, initiate an emergency shutdown according to 8.2.3.2.

8.3.7 Shutdown in case of breakaway activation

The disconnection of the breakaway should (directly or indirectly) terminate the fuelling process and isolate the fuelling hose assembly up-stream of the breakaway.

8.3.8 Physical disturbance of the dispenser

The risk assessment conducted according to 5.2 should consider possible accidents and incidents and, if physical measures are not adequate, detection of physical disturbance should be incorporated, for example using a tilt sensor, and subsequent emergency shutdown.

8.3.9 Hazardous area around the dispenser

By design according to ISO 17268, and the performance of pressure integrity tests (8.2.2.4.3) the fuelling hose assembly, including whilst connected to the vehicle receptacle, is bubble free, even during uncoupling of the receptacle and nozzle.

The utilization of the mitigation measures described above for leak detection, see 8.2.2.4.3 and 8.2.3.5, reduce the probability of a leak and the persistence time. Therefore the presence of an explosive atmosphere around an open air fuelling hose assembly is not expected, and no hazardous area, see 5.5.2, is considered around the fuelling hose assembly.

8.4 Hydrogen quality

The hydrogen quality at the nozzle should be consistent with the requirements of ISO 14687-2.

As the Fuel Cell Electric Vehicles (FCEV) industry matures, the list of impurities in ISO 14687-2 and their thresholds should be revised appropriately and according to technical progress, taking into account:

— proven detrimental effect to fuel cell vehicle systems;

— feasibility of measurement of very low concentrations;

— complexity of appropriate purification, sampling and analysis.

8.5 Hydrogen quality control

8.5.1 General

Hydrogen fuelling stations are used for fuel cell electric vehicles which are powered by PEM fuel cells. Fuel cells are sensitive to some critical impurities, such as CO and components of sulphur. Without control of these impurities, there could be significant performance and durability issues.

A quality assurance system should be implemented for the whole hydrogen supply chain in order to avoid damage to the fuel cell vehicles.

Since the likelihood of contamination depends crucially on the hydrogen supply chain (from source to nozzle, including transport and compression), not all impurities need be tested for at all times. Analysis of the whole supply chain will allow station operators to identify quality risks and modify testing specifications, while maintaining the same quality assurance and limits.

NOTE An example of the impurities of concern is shown in Annex C, Tables C.1, C.2 and C.3.

The specific list of impurity constituents should take into account the impurities that could occur in the fuelling station operation and maintenance processes. Fuelling station manufacturers should inform the fuelling station operator of impurities that could occur, and to specify preventive measures to ensure hydrogen fuel is within specification limits. Impurities could occur from lubricants, heat transfer fluid and cleaning of hardware in contact with hydrogen.

Hydrogen quality measuring for impurities relevant to the supply chain, whether delivered or onsite production, should be carried out before the onsite fuelling station acceptance test and repeated after an appropriate period. Following the first acceptance test, the testing frequency should be repeated as a minimum annually.

Fuelling stations with onsite hydrogen production or purification equipment should have a continuous monitoring of one or more critical canary species, or a process control system to ensure that the hydrogen gas at the nozzle meets the specification in 8.3 (see also Table C.1).

Hydrogen quality measuring should be conducted, according to the risk assessment, after maintenance which may cause contamination of hydrogen fuel.

If the fuelling station cannot meet the quality mentioned in 8.3, corrective action should be taken before other vehicles are permitted to fuel. Corrective measures should be put in place and fuel quality assessments conducted until the hydrogen is again within specification.

Periodic sampling of hydrogen should be done at the fuelling nozzle and should only be done by personnel trained in handling of pressurized hydrogen gas. A representative sample should be considered utilizing hydrogen from all hydrogen banks at fuelling station.

8.5.2 Dispenser fuel filters

To prevent hydrogen containing function-impairing impurities (i.e. particulates) that would affect the high pressure hydrogen system of FCEV, specifically the vehicle CHSS valves, hydrogen filters should be included as part of the dispenser, see 9.9. There should be a filter with a capability to prevent particulates of a maximum size of 5 µm with a minimum removal efficiency of 99 % under expected process conditions, or alternatively a 5 µm filter. The filter should beinstalled upstream of, and as close as possible to, the hose breakaway device. This should filter out the particulate concentration in the hydrogen according to ISO 14687-2.

NOTE ISO 4022, ISO 12500-1 and ISO 12500-3 provide recommended methodologies for the testing of filter efficiencies.

9 Equipment and components

9.1 General

9.1.1 General equipment recommendations

Equipment should be designed for the expected operating conditions, and specified ambient conditions.

Components that may need to be dismounted for maintenance should be installed in such a manner that dismounting and remounting does not damage or untighten other components. If a specific procedure is to be applied to avoid this, a reference to this procedure should be made by signage.

All parts that may be contacted during normal servicing and operation should be free from sharp projections or edges and projecting screw ends.

All components that are routinely serviced should be accessible for servicing and functional adjustment in position and should be replaceable during normal servicing.

9.1.2 Material hydrogen compatibility

Components in which hydrogen are processed, as well as all parts used to seal or interconnect the same, should be resistant to the chemical and physical action of hydrogen at the operating conditions. In particular, when selecting materials and manufacturing methods, due account should be taken of resistance to hydrogen assisted corrosion.

The materials (steels, aluminium and polymers, etc.) utilized need to be compatible with hydrogen at the temperatures and pressures utilized. Due consideration should be given when selecting ferrous materials for hydrogen service. Further information on the selection of materials, particularly the choice of steels resistant to hydrogen embrittlement can be found in ISO/TR 15916 and ISO 11114-1. ISO 11114-4 can be used to determine the test methods for selecting metallic materials resistant to hydrogen embrittlement.

NOTE Hydrogen embrittlement is commonly addressed by material selection, conservative design (avoid yielding), manufacturing process and surface finish.

Cast iron, malleable iron and grey iron pipe and fittings should not be used due to the permeability of hydrogen and the possibility of porosity.

Vent lines, where hydrogen is not expected to be present under normal operating conditions, or at sustained high pressures, may use other materials not suitable for high pressure hydrogen service.

9.1.3 Hydrogen and material compatibility at cryogenic temperatures

Equipment and components that are to be used for handling liquid hydrogen and other gases under cryogenic conditions should meet the material recommendations of the equipment and component standards specified in 9.1.1. A guide for material compatibility in cryogenic service is given in ISO/TR 15916, ISO 21010 or ISO 21028-1.

9.1.4 Other material recommendations

The materials of construction, or byproducts of the degradation of the materials of construction should not adversely affect the environment. Material selection should be made in accordance with local environment requirements, avoiding the use of materials that do not comply with these requirements such as: mercury, lead or asbestos.

Care should be taken to prevent contact between dissimilar metals to prevent galvanic corrosion. When an electrolyte is expected to be present, the use of dissimilar metals in tubing, fittings and other components should be avoided. Special consideration should be given to prevent contact between components of anodic metals with cathodic ones. Metal fittings should be compatible with metal tubing materials.

9.2 Piping carrying gaseous hydrogen

9.2.1 General

Piping used to transport hydrogen in the fuelling station should conform with ISO 15649, or with a national/regional standard, such as a Harmonised standard, and be suitable for the anticipated cycle life. Piping and fittings should be made of materials compatible with hydrogen service, see 9.1.2.

High pressure components should be mounted in strict compliance with the supplier's instructions, following a well-defined assembly procedure.

High pressure piping should be welded in accordance with a national / regional standard, such as a Harmonised standard. This includes qualification of welders, welding procedures etc.

Piping should be installed so it is not accidentally stepped on or used for leverage, and does not present a trip hazard for users or service personnel.

Where necessary, hydrogen piping may be run below grade, preferably in an open trench covered by a grating. If non-welded joints are used, particular attention should be given to their location considering the potential impact of a leak on personnel safety and equipment integrity. Buried gaseous hydrogen pipes should use welded joints. Where non-welded joints are used, they should be accessible from the surface and be of a high integrity leak tight design.

Piping that might be exposed to corrosive environments (e.g. underground pipes or pipes in trenches) should be protected from corrosion by suitable means.

9.2.2 Piping, fittings, valves, regulator for cryogenic service

Valves used for cryogenic service is should comply with ISO 21011.

Means should be provided to minimise exposure of personnel to piping operating at low temperatures and to prevent air condensate from contacting piping, structural members and surfaces not suitable for cryogenic temperatures.

Uninsulated piping and equipment, which operates at below air condensation temperature, should not be installed above asphalt surfaces or other combustible materials in order to prevent contact of liquid air, asphalt and bitumastic paving should be considered combustible for oxygen dripping. If expansion joints are used, fillers should also be made of non-combustible materials. Drip pans may be installed under uninsulated piping and equipment to retain and vaporise condensed liquid air.

9.3 Hydrogen storage recommendations

9.3.1 Gaseous hydrogen storage vessels

Storage vessels for the storage of hydrogen gas should be manufactured in accordance with a commonly used national/regional standard and designed for the anticipated cycle life.Buffer storage may include hydrogen absorbed in a metal hydride storage system.

If buffer storage tanks of different design pressures are interconnected, they should be protected in such a way that tanks rated for a lower pressure cannot be over-pressurized due to any malfunction.

If composite tanks are used for buffer storage, the design of the installation should include means to prevent bursting in the case of fire. Suitable prevention methods may include:

— product venting systems, such as thermally activated pressure relief devices (TPRDs);

— thermal shielding;

— fixed firewater protection, where permitted according to national regulations.

The layout design of the gaseous hydrogen buffer storage tanks should prevent direct impingement of any gas leak onto an adjacent vessel.

Each group of buffer storage tanks that may be isolated with manual or automatic valves, should be equipped with their own set of safety devices.

When hydrogen is delivered in transportable cylinders, tube trailers or MEGCs, these may not include safety relief devices within the cylinder / group of vessels.

However, when transportable cylinders, tube trailers or MEGCs are incorporated into a fuelling station, following appropriate risk assessment that addresses the potentially different design considerations, particularly pressure cycling, any on-site compression system that may compress hydrogen into such a system should include a set of safety devices to protect the storage tube(s) from over-pressurization.

9.3.2 Hydrogen storage siting recommendations

9.3.2.1 Ground storage

Gaseous hydrogen buffer storage tanks or assemblies should be situated in the open air or a suitable hydrogen safe container, see 5.6.3. The foundation for a gaseous hydrogen storage tank should be appropriate to accommodate the weight of the equipment placed on it and should be made of concrete or any other suitable non-combustible material.

9.3.2.2 Below ground vaults

Below-ground vaults constructed on-site should be designed in accordance with a national building code. Inspections should be conducted to verify structural strength and compliance of the installation with the approved design. Consideration should be given to soil and hydrostatic loading on the floors, walls and roof, anticipated seismic forces, uplifting by ground water or flooding, and to loads imposed from above, such as traffic and equipment loading on the vault roof.

The vault walls should be higher than the gaseous hydrogen buffer storage tanks contained therein. There should be no openings in the vault enclosure except those necessary for access to, inspection of, and filling, emptying, ventilation and venting of the gaseous hydrogen buffer storage tanks. Means of ventilation should be provided to prevent accumulation of leaked hydrogen gas. Ingress of water should be prevented, or minimised where a drainage system to manage water ingress is provided. If installed at grade and subject to vehicle loading, the top should have a metal grating or another roof with sufficient strength to carry vehicle loading.

If manual intervention is required for safe operation or in an emergency, manually operated valves or controls, should be located above ground and accessible to authorized personnel only.

There should be sufficient clearance between the gaseous hydrogen buffer storage tanks and the vault to allow for visual inspection and maintenance of the tanks and their appurtenances.

Where adjacent vaults share a common wall, the common wall should be liquid and vapour tight and should be designed to withstand the load imposed when the vault on either side of the wall is filled with water

Pressure relief devices should be vented to a safe location as specified in 5.4.5.

Vaults should be designed in accordance with 5.9.1. At each entry point, a warning sign indicating the need for following procedures for safe entry into confined spaces should be posted. Entry points should be secured against unauthorized entry and vandalism.

9.3.2.3 Roof top installation of gaseous hydrogen systems

9.3.2.3.1 General

Where hydrogen generators, compressors, gaseous buffer storage tanks, piping systems and their related accessories are located on building or canopy roofs, the installation should meet the recommendations of 9.3.2.3.

Equipment installed at heights should have walkways and working platforms to facilitate worker access and be accessible for inspection and maintenance. Measures to address the hazards of working at heights should be taken to protect workers from falling off the roof, and to protect persons below the equipment / elevated from falling objects.

Access to the building or canopy roof should be provided in accordance with ISO 14122.

9.3.2.3.2 Roof structural recommendations

The roof structure supporting the hydrogen equipment and tanks should be constructed in compliance with the local national building code with due consideration for the added weight of the equipment in addition to other static and dynamic loadings.

9.3.2.3.3 Gaseous hydrogen storage mounting

Gaseous hydrogen buffer storage tanks should be mounted according to the tank manufacturer's instructions. They should be individually supported in a cradle or similar structure or within a rack that provides individual tank support.

The tank mounting structure should be securely affixed to the roof.

9.3.2.3.4 Other hydrogen equipment mounting

Other hydrogen equipment should be securely mounted on the gaseous hydrogen storage mounting structure or separately mounted to the roof.

9.3.2.3.5 Fire protection

Gaseous hydrogen equipment and buffer storage tanks on the roof of an occupied building should meet the following recommendations to avoid escalation from a building fire:

— Measures should be provided to avoid overpressure/explosion of the hydrogen storage systems in case of fire, such as fire detection, emergency device to empty the storage, such as thermally activated pressure relief devices (TPRDs), or a sprinkler system;

— The supporting roof structure and columns below the hydrogen equipment and storage footprint area should have a minimum fire-resistant rating, not less than that required by the type of construction for the building.

9.4 Hydrogen compressors

9.4.1 General

Compressors should be designed with particular reference to hydrogen service and to minimize the introduction of contaminants.

Each compressor should be equipped with a pressure relief device to prevent overpressure.

Where multiple compressors are installed in parallel, and operated during maintenance activities, positive isolation should be provided to isolate any compressor being worked on.

Each compressor should be equipped with means to fully depressurize all parts of the system for maintenance purposes.

When the risk mitigation review of a compressor system recommends the use of an inert purge, means (written procedure) to purge the compressor(s) with inert gas prior to maintenance operations should be provided to control in an effective inerting.

Compressor enclosures should comply with 5.4.4 and 5.6.3.

9.4.2 Vibration and movement

Sufficient compensation for vibration and movement should be provided between interconnected systems at a hydrogen fuelling station and between the hydrogen gas supply piping and the compressor suction piping to avoid leaks caused by vibration and movement.

Any vibrations that may affect the strength of the piping, fitting and component should not be transferred to the piping work.

9.4.3 Control and monitoring

9.4.3.1 General

Safety controls should be installed to ensure temperature and pressure levels do not exceed or fall below set operating levels.

In addition to the instruments and controls normally provided for gas compressing systems, the following specific safeguards for hydrogen should be considered.

9.4.3.2 Inlet pressure

Ingress of air at the inlet to the compressor should be avoided at all times to prevent the formation of an explosive mixture. If this condition is no longer guaranteed, the compressor should be shut down.

For example, the inlet pressure should be monitored by a pressure indicator/switch to avoid a vacuum in the inlet line and consequent ingress of air. This pressure indicator/switch should cause the compressor to shut down before the inlet pressure reaches atmospheric pressure.

If there is a possibility of oxygen contamination under normal operating conditions, measurement of the oxygen content in the hydrogen can be considered as a mitigation measure during risk assessment. For example, should the oxygen content reach a volume fraction of 1 %, the compressor can be automatically shut down. Alternative means can be taken to prevent critical situations.

9.4.3.3 Discharge temperature

The temperature after the final stage of compression, or the temperature after the cooler, where fitted, should be monitored by an indicator/alarm that should be arranged to shut down the compressor at a predetermined maximum temperature.

9.4.3.4 Discharge pressure

The pressure after the final stage of compression should be monitored by an indicator/alarm, which should be arranged to shut down the compressor or initiate alternative actions, such as recycling, at a predetermined maximum pressure which is below that of the final pressure relief device.

9.4.3.5 Cooling water — low pressure alarm

A water pressure alarm should be provided in the cooling water system, which should indicate the need to shut down the compressor in case of low pressure or flow.

9.4.3.6 Purge gas on electrical equipment

Where the motor and auxiliary equipment are pressurized by an inert gas such as nitrogen, low pressure/flow should be indicated by an alarm, which should be arranged to shut down the motor and auxiliaries as required by IEC 60079-2.

9.4.3.7 Pressurized crankcases

Where the compressor crankcase is pressurized by nitrogen or other inert gases, low pressure/flow should be indicated by an alarm, which should be arranged to shut down the compressor.

The compressor design should prevent the formation of an air and hydrogen mixture in the compressor crankcase.

If the crankcase is protected by a safety valve, the valve should be vented to a safe location.

9.5 Cryogenic pumps

9.5.1 General

Foundations for cryogenic pumps should be designed and constructed to prevent frost heaving.

Surfaces located under the pump's connections and under uninsulated hydrogen piping should be constructed of non-combustible materials according to 9.2.2.

Each cryogenic pump should be provided with a vent and a pressure relief valve that will prevent over-pressurizing of the pump case under all conditions, including the maximum possible rate of cool down.

Operation in presence of cavitation should be prevented if identified as a safety relevant factor, for instance by an anti-cavitation system activating automatic shutdown of the pump.

ISO 24490 can be used as a reference for the design of cryogenic pumps.

9.5.2 High pressure vaporizer

The vaporizer and its piping should be protected with pressure relief devices.

The vaporizer should be sized for the maximum flow requirement specified for cryogenic pumps. The vaporizer system should be designed as required despite accumulation of ice due to condensation of ambient moisture.

Where necessary, a device should be installed to ensure that cold gas temperature exiting the vaporizer cannot:

— affect the dispensing process;

— cause damage to pipe work and equipment downstream.

Heat used in the vaporizer should be indirectly supplied utilising media such as air, steam, water, or water solutions.

Means to stop flow should be installed should low temperature downstream of the vaporizer be detected.

The vaporizer should be anchored and its connecting piping should be sufficiently flexible to provide for the effect of expansion and contraction due to temperature changes.

Suitable means should be installed on the vaporizer discharge to avoid the possibility of liquid hydrogen from entering a gaseous hydrogen storage or other equipment not designed for liquid hydrogen temperatures. The combustion air required for the operation of the primary heat source for remote heated vaporizers should be taken from outside an enclosed structure or building. A device should be fitted after the hydrogen vaporizer to avoid back flow into the hydrogen system.

When a water bath or steam heated vaporizer is used, the maintenance schedule should include a regular visual examination of shell and external tube surfaces for signs of damage, excessive frosting etc. Any defects should be reported to the supplier.

9.6 Pressure relief devices for gaseous hydrogen systems

When required, the pressurized gaseous hydrogen systems and equipment should be protected from over-pressure e.g. by use of one or more PSD(s), or by other appropriate means. A PSD can be of the self-destructive type, such as rupture disks and diaphragms, or of the resealable type, such as PSV spring-loaded pressure relief valves.

PSVs should meet the requirements of ISO 4126-1 or an equivalent standard recognized in local regulation.

Burst disc safety devices should meet the requirements of ISO 4126-2 or an equivalent standard recognized in local regulation.

The equipment should be protected against excessive pressure at all times during operation. Consideration should also be given in the design of the installation to facilitate the periodic testing of the pressure relief devices. EN 764-7 provides guidance on isolation of relieving safety systems.

Isolation of the pressure relieving safety accessory(ies) from the equipment which it is designed to protect should only be permitted if the source of pressure, which could lead to an unsafe condition, is simultaneously isolated from the equipment with the pressure relief device. Prior to isolation the continued need to protect against external sources of overpressure such as solar radiation and fire should be addressed.

Where multiple relieving safety accessories are used, any provision made for isolating any one relieving safety accessory (e.g. for testing or servicing) should ensure that the remaining relieving safety accessory(ies) connected to the equipment provide the full relief capacity required.

Acceptable methods include but are not limited to:

— 3-way valves;

— changeover valves;

— mechanical interlocks;

— captive sequential key interlocking.

In some cases, isolation valves may be used for maintenance of pressure relief devices if the isolation valve can be locked open whenever the equipment being protected is being pressurised. Access to the lock key should be controlled and used by qualified service personnel only, with the position of the valve and the locking device checked periodically. In such cases, a bleed valve should be used to depressurize the line upstream of the PRV and ensure safety during maintenance operation.

9.7 Valves for gaseous hydrogen

Isolation valves should be used to isolate portions of the piping system in emergencies and for routine maintenance. Where manually operated emergency isolation or vent valves are included, these should be installed at an accessible location in the hydrogen piping so that the hydrogen flow can be shut off when necessary.

Means to safely relieve pressure and purge with hydrogen after maintenance should be provided.

A standard operating procedure should insure a safe and efficient hydrogen purging of the system with high purity hydrogen after maintenance operation of all kinds and prior to use. The purpose of the hydrogen purging is to remove any chemical and particulate contamination before restarting the plant in operation. Hydrogen gas quality analysis may be required to confirm that the dispensed hydrogen quality meets the expectation defined in 8.3 and 8.4, before restarting dispensing operations.

9.8 Instruments for gaseous hydrogen

Instruments dedicated for various functions on the fuelling station should be tested and proved qualified for their intended purpose.

Instruments and gauges should be designed and located such that, in the event of a leakage or rupture, and possible subsequent fire, the risk to personnel is minimised. Safety “glass” and blowout backs on pressure gauges should be used.

Cabinets or housings containing hydrogen control equipment should be designed to prevent any accumulation of hydrogen gas.

9.9 Filters for gaseous hydrogen

Filters and separators should be sized for the maximum hydrogen gas flow and for the expected impurities in the hydrogen gas, see 8.4.2, and, where appropriate, should be provided with sufficiently large sumps or collecting tanks. As far as possible, filters and separators should be combined in a single unit. The filters should have a specified separating capacity. Where liquids and condensation products require removal, consideration should be given to the dew point of these liquids, relative to the temperatures to which hydrogen is cooled prior to passing through the separator, to avoid freezing and blockage.

Clogging of the filter insert in the main hydrogen gas flow should be monitored. This may be done by regular preventive maintenance, by regular operational checks or by monitoring equipment, e.g. differential-pressure gauges indicating a maximum value, as specified by the filter supplier.

The filters and separators should be arranged and installed in such a way that it is possible to open and empty them in a safe manner. In the event of frequent opening and closing operations, the filters and separators should be fitted with quick opening and closing fittings.

Where a separator is needed for removing liquids and condensation products, a manual or an automatic discharging device, if applicable comprising a sump, should be provided.

The filter should be accessible for inspection, cleaning and replacement of the filter element.

9.10 Dispensers

9.10.1 Location and protection of dispensers

The dispenser may be a stand-alone device on the fuelling station forecourt, or may be integrated as part of a hydrogen production / compression container unit. Necessary physical protections should be implemented to protect the dispenser from any vehicular impact.

NOTE Examples of methods that can be used to achieve adequate protection are described in Annex E.

The structural foundation of the dispenser and the fuelling area should be adequate to support all components including vehicles to be fuelled.

Dispensers should be secured against unauthorized use outside normal operating hours. The hydrogen supply to the dispenser should be isolated at the source and dispenser according to 9.10.3.3.

Dispensers should not be located beneath a canopy unless the canopy has been designed to prevent the accumulation of hydrogen in pockets or between the canopy ceiling and roof, or other means of protection have been taken.

9.10.2 Fuelling pad

The vehicle fuelling pad should be made of non-combustible materials and designed to allow electrical grounding before the nozzle is connected to the vehicle. The fuelling pad should have a common ground (earth connection) with the station equipment. The electrical resistance between the vehicle fuelling pad and the dispenser ground should be less than 1 MΩ.

The vehicle fuelling pad should be level, except for a minimal slope to provide normal surface water drainage.

9.10.3 Dispenser system design

9.10.3.1 General design and assembly

The dispensing system should be designed to perform compressed hydrogen fuelling according to a defined fuelling protocol and incorporate the required critical safety equipment to safeguard the users and vehicles against any over-pressure, over-filling and major hydrogen release situations (see 8.2).

The connection interface of the fuelling assembly to the dispenser should be such as to prevent the mounting of a fuelling nozzle designed for 35 MPa fuelling on a 70 MPa dispenser.

Dispensers should be equipped with means to secure and protect the fuelling nozzle and hose(s) against external mechanical aggression and contamination by foreign materials when not in use.

A means to depressurise and/or purge the dispenser should be provided and should be protected by a locking mechanism or permanent closure so that it is inaccessible to the public.

9.10.3.2 Rated operating conditions

All the components in hydrogen service should be covered by a technical specificatio providing the necessary recommendations, based on the dispenser operating conditions defined in the table below.

All the components of the dispensing system should be rated for, as a minimum:

— a maximum allowable working pressure (MAWP) equal to or greater than 138 % of the dispenser nominal working pressure (H35 or H70 as defined in ISO 17268);

— an ambient temperature range of −40 °C to +50 °C; (consideration should be given to the possibility of higher temperatures, with the use of protection from the sun and/or higher rated components where necessary)

— use with hydrogen;

— a specified cycle life beyond which the component should be removed from service.

It is recommended that dispenser components are rated for use at the MAWP listed below in Table 5, and tested as a minimum to the appropriate Integrity Test Pressure (ITP) for their pressure class.

NOTE Further guidance on pressure terminology is included as Annex D.

When components in the dispensing system have a lower maximum allowable working pressure than 138 % of nominal working pressure (NWP), the set point of the PSV should be defined by the lowest maximum allowable working pressure of any component in the relevant pressure system. The fuelling protocol should take this restriction into account to minimise the likelihood of over-pressurisation of the dispenser.

Table 5 — Pressure levels for dispensing system components

Pressure Class	**NWP (Nominal Working Pressure)** **due to a CHSS gas temperature of 15 ºC**	**MOP** **(Maximum Operating Pressure)** **Highest pressure permitted during normal fuelling due to a CHSS gas temperature of 85 ºC**	**MAWP 1** **(Maximum Allowable Working Pressure)** **Minimum pressure to which component is rated** **Highest permissible dispenser PSV set-point – see 8.2.3.3**	**ITP 2, 3** **(Integrity Test Pressure)** **Minimum pressure to which component is tested before use.**
	1,00 x NWP	*1,25 x NWP*	*1,375 x NWP*	*1,50 x NWP*
H25	25 MPa	31,25 MPa	34,375 MPa	37,5 MPa
H35 4	35 MPa	43,75 MPa	48,125 MPa	52,5 MPa
H50	50 MPa	62,5 MPa	68,75 MPa	75,0 MPa
H70 4	70 MPa	87,5 MPa	96,25 MPa	105,0 MPa
NOTE 1 Component rating to be valid at maximum and minimum allowable material temperatures as defined by the manufacturer; NOTE 2 The proposed test level matches the maximum pressure expected during PSV relieving; NOTE 3 Other test pressure required according to national regulations; NOTE 4 Pressures used for hydrogen road vehicle fuelling in this document. NOTE 5 The ratio between MOP and MAWP is different (greater or lower than 1,1) depending on the processor design of the hydrogen fuelling station and corresponding sub-systems (for example in Japan). NOTE 6 ITP is either a hydraulic or pneumatic test.				

9.10.3.3 Dispenser hydrogen isolation valves

Means to automatically isolate all hydrogen dispensers from the hydrogen supply should be included.

The manufacturer's risk assessment should consider the need for an automatic isolation valve to be provided at each end of the pipe between the dispenser and the hydrogen buffer storage, dependent on the amount of hydrogen that would be released in case of a loss of containment. At least one automatic isolation valve should be located in a place not accessible to public, and protected from vehicle impact.

Where required, the automatic valve at the dispenser should be located such that it is protected from vehicular impact.

The automatic valves should be normally-closed. The automatic shut-off valves should be closed if an emergency shutdown occurs as defined in 8.2.3.2 and when no dispensing is taking place. While the automatic shut-off valves should open to allow dispensing, these valves should not perform process control as described in 8.2.2.4.6.

Means to provide positive isolation of the dispenser automatic shut-off valve and of the dispenser, for example using manual shut-off valves, should be included where appropriate for maintenance.

The leak-tightness of the isolation valves should be periodically checked.

Where required by risk assessment, the isolation valve body should be constructed with material that will continue to function in the case of engulfment in fire.

9.10.3.4 Dispenser cabinet

The construction of the cabinet should be such that it will not become warped, bent, loosened or otherwise damaged in normal operation. The dispenser cabinet should:

— be able to withstand the expected service loads;

— be made from non-combustible and antistatic materials.

A recess or depression in the cabinet that may collect water should contain means to drain the water to an area that will not cause an unsafe condition.

The dispenser cabinet should afford space for making field connections of gas-carrying piping and electrical equipment. Openings should be provided for making connections and for inspection and adjustment of the operating mechanism after installation. Openings should require a key or tool to open.

The equipment and parts within the dispenser cabinet should comply with the recommendations of 10.2.2. The interior of the dispenser cabinet should be naturally- or force- ventilated to prevent flammable mixtures in case of a reasonably foreseeable leak. This may be achieved by openings at different elevations so as to ensure sufficient ventilation. Ventilation outlets should be located in a way as to avoid exposure of the user. Pressurized gases emerging from pressure relief devices should be ventilated and dissipated in a safe manner to a safe location outside the dispenser cabinet, avoiding any flammable gas atmosphere within the dispenser cabinet.

9.10.3.5 Dispenser piping and fittings

The dispenser piping and fittings should comply with the recommendations of 9.2.

9.10.4 Dispenser fuelling assembly

9.10.4.1 General

A dispenser fuelling assembly should consist of a breakaway device, a hose(s), a nozzle and connectors between these components.

Suitability of the fuelling assembly components for the specified service conditions and cycle life should be demonstrated by type testing. Type testing to enable a rated pressure to an MAWP of 1,375 % NWP could for example include:

— a hydrostatic pressure test to 375 % NWP;

— 100 000 pressure cycles to 125 % NWP;

— 10 pressure cycles to 150 % NWP.

Where a MAWP of a lower ratio of 137,5 % NWP is used, the test pressures above may be lower.

The maximum and minimum operational temperatures of the fuelling assembly components should be used during type testing, i.e. see 9.10.3.2.

Each fuelling assembly component should have been hydraulically tested by the manufacturer to a minimum 150 % of the nominal working pressure, see 9.10.3.2, and had a certificate issued to that effect.

NOTE National requirements can require a higher test pressure for assemblies/components as well as the involvement of third party inspection.

9.10.4.2 Composition and integration

The hose breakaway device should be positioned such that when the fuelling hose is pulled along its axis, it will release without damage to the dispenser cabinet. If the fuelling assembly includes a venting hose, the latter should also be fitted with a breakaway device.

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

9.10.4.3 Prevention of damage to fuelling assembly in service

Between fuelling, the hose assembly and nozzle should be stored in such a way that they are protected from damage by vehicles.

The hose assembly should be prevented from contacting the ground unless appropriate measures are taken to protect the hose from any damage resulting from contact with the ground.

The hose assembly should be prevented from being bent to the point of damaging the hose in the conditions of use that are likely to occur.

9.10.4.4 Electrical continuity

Electrical continuity should be ensured throughout the fuelling assembly. The outer surface cover should be non-conductive. The total electrical resistance between the (vehicle) end of the fuelling nozzle to the station electrical ground should be a maximum of 1 000 Ω.

The resistance should be measured equal to the manufacturer’s specified maximum allowable working pressure.

9.10.4.5 Marking

The fuelling assembly components should be individually marked with:

— the manufacturer’s name or trademark;

— the model designation;

In addition, the fuelling assembly components should be marked with either the date of manufacture or testing, or a serial or batch number, to enable traceability of the component to a test report or certification.

Where appropriate, reference should be made to the design standard with the appropriate pressure class, H25, H35, H35HF or H70 identified.

Where this isn’t applicable, the component should be marked with:

— the maximum allowable working pressure;

— permissible operating temperature range; and

— suitability for use with hydrogen.

Breakaway couplings should be marked with the direction of gas flow.

The markings should be designed to be permanent throughout the expected lifetime of the component.

9.10.4.6 Assembly and installation

The components of the fuelling assembly should be assembled and installed according to the manufacturer's instructions.

9.10.4.7 Maintenance and inspection

The fuelling assembly should be visually inspected regularly to check that the assembly is free from damage.

The fuelling hose should be visually inspected regularly to check that the hose is free from damage, cuts, cracks, bulges or blisters, and kinks.

The fuelling assembly should be periodically tested for leaks with a compatible leak detection fluid. Any leakage should be reason for rejection.

The use of protective covers and/or automatic leak tests should be used to define the frequency of visual inspection.

Fuelling hose assemblies that fail visual inspection or leakage test should be withdrawn from service.

9.11 Hose assembly

9.11.1 Rated operating conditions

The hose should be rated for the conditions specified in 9.10.3.2.

9.11.2 Hose assembly design

The hose should be designed for hydrogen service and the environmental conditions at site of use.

Hydrogen leakage by permeability should not exceed 10 cm^3/h per metre of hose at 20 °C.

Construction and materials should be such as to prevent the trapping of hydrogen within or between the materials at a pressure that could damage the hose when the internal pressure is relieved.

Metal mesh reinforcement should not be susceptible to corrosion from penetration of humidity, if such penetration is reasonably foreseeable during expected lifetime.

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

The length of the fuelling hoses should be long enough to fill vehicles, but should not be longer than necessary to fill vehicles at the intended location.

9.11.3 Hose assembly type testing and production testing

For rated pressures of up to 45 MPa, the fuelling hose assembly should be type tested and production tested according to ISO 14113.

9.11.4 Venting hose assembly

The venting hose, if present, is subject to the same recommendations as the fuelling hose, as defined in 9.10.4.2 to 9.10.4.7.

9.12 Fuelling connector (nozzle) general design and assembly

9.12.1 General design and assembly

The fuelling nozzle should comply with ISO 17268 or SAE J2600 and be rated for the appropriate pressure class. The use of adapters should be prohibited.

The fuelling nozzle should be securely supported and protected from the accumulation of foreign matter (e.g. snow, ice or sand) that could impede operation.

The fuelling nozzle should prevent the entry of air into the vehicle fuel system and fuelling station equipment.

9.12.2 Depressurization of nozzles

A mechanism should be provided to depressurize nozzles as required in ISO 17268.

The gas should be vented in a safe manner to a safe location.

9.13 Hose breakaway device general design and assembly

9.13.1 Rated operating conditions

The hose breakaway device should be rated for the conditions specified in 9.10.4.1.

The hose breakaway device should disconnect when subjected to a maximum force of 1000 N but not less than 220 N independent of the operating pressure within the device when installed as specified by the manufacturer. This condition should be met at all operating fuelling pressures.

The hose breakaway on the fuelling line should incorporate double shut-off features that isolate both sides of the connection when uncoupled.

A method requiring the use of tools should be provided to reconnect the hose breakaway device if it is not a “one-time-use device”. In the event of a reconnection, the fuelling hose assembly should be pressurized and leak tested under operating conditions before recommencing operation.

9.13.2 Breakaway durability

The hose breakaway device should withstand 100 000 cycles of hydrogen gas pressure pulses without separation or leakage. The breakaway device should be inspected and tested according to the supplier’s maintenance scheme.

9.14 Gaseous hydrogen vent systems

9.14.1 General

The venting of hydrogen is typical in a hydrogen fuelling station, and measures should be taken to ensure that hazards arising from venting are minimised, see 5.4.5.

Hydrogen venting systems should be designed and sized according to the following considerations.

9.14.2 Piping design

Design pressure should be such that the pipe system will not rupture in the event of detonation of a flammable hydrogen air mixture in the system. The vent system should be designed for the thrust of the discharging jet.

The recommendations of 9.1.2 should be applied. Vent piping of cryogenic hydrogen should not be insulated to allow the maximum heat transfer from atmosphere in order to reduce the probability of cold hydrogen vent gas vapor clouds. Thermal contraction should be accounted for.

9.14.3 Flame arrestors

Flame arrestors are not needed for vent systems that follow the recommendations of this document.

NOTE Flame arrestors are typically used on combustion systems such as a pre-mixed air fuel supply to a hand torch for example. Flame arrestors can apply a backpressure to increase velocity at the “fire check”.

Back pressure devices used on hydrogen vent systems with gas recovery or atmosphere exclusion systems should be engineered for the specific hydrogen vent recommendations.

9.14.4 Vent outlet

Outlet may be vertical upwards, horizontal, or any direction in between. Caps should not be used.

Drains and water accumulation points should be protected from freezing to avoid blockage or breaking of vent stack. Consideration should be given in the fuelling station risk assessment to the prevention of accumulation of water, including that from condensation, in the vent stack outlet (or other requirements for protection against freezing.)

Where the risk assessment deems appropriate, vent systems, particularly those with a vertical outlet should be equipped with a water drain valve at the bottom of the vent stack.

For horizontal outlets (T-vent or single outlet vent), the cut plane should not face downward if the exit velocity is sufficiently high for the direction of the release to be determined by the orientation of the cut plane.

The outlet piping may be slightly inclined downwards to avoid entry of water if measures are taken to avoid that the plume or jet will be pointing downwards (e.g. through low velocity release, or by use of a cut plane facing upwards for exit velocities that are sufficiently high for the direction of release to be determined by the orientation of the cut plane.

9.14.5 Maximum flow rate calculation

The maximum flow rate should be calculated as the sum of all the flows in normal or foreseeable operating conditions that are expected to be simultaneous, and the highest flow generated by upset conditions.

Normal and foreseeable operating conditions to be considered are, for example, the venting of compressor flow. For liquid hydrogen supply systems, normal and foreseeable operating conditions include:

— cool down of lines, pumps and connected equipment;

— liquid flash and gas displacement during filling of the tank;

— normal boil-off rate from ambient heat leak.

Upset and accidental conditions maximum flow rate should include the largest of the following independent upset conditions such as

— emergency discharge of gaseous hydrogen buffer storage;

— external fire;

— malfunction of dispensing control valve causing pressure relief valve(s) to open.

For liquid hydrogen supply systems: Upset and accidental conditions maximum flow rate should include

- excessive rate of cool-down;
- loss of vacuum;
- malfunction of control valves in the pressure control circuits or fuelling line causing excess vapour generation in the tank;
- venting of pumped liquid flow.

9.14.6 Piping diameter and exit velocity

The vent piping diameter should not be smaller than the diameter of any pressure-relief valve outlet, and large enough to prevent the pressure relief valve functioning properly. Limitation of noise level may also need to be considered.

NOTE 1 For vertical venting, the higher the discharge velocity the smaller the separation distance recommendations around the vent [1)].

NOTE 2 For T-venting, the smaller the discharge velocity the smaller the separation distance recommendations in the axis of discharge [2)].

9.14.7 Maximum pressure drop

The maximum pressure drop resulting from the sum of design flows of all vent devices discharging into a common vent system at the same time should not exceed 10 % of the lowest set pressure of these relief valves, in order to prevent counter-pressure in the vent line from preventing the opening of the relief valve.

9.15 Pneumatics

Instrument air from an air compressor or cylinder supply system should be supplied through control valves. A buffer volume should maintain the air pressure to allow a safe shutdown of the fuelling station should the supply lapse. Pneumatic equipment and systems should satisfy the requirements of ISO 4414.

Pneumatic systems should be designed so that no hazard may result from pressure losses, pressure drops.

All elements of the pneumatic system, especially pipes and hoses, should be protected against harmful external effects where this is required by the fuelling station risk assessment.

9.16 Hydrogen purifier

Hydrogen purification should be provided as necessary to meet the recommendations of 8.3 and 8.4 under all operating conditions where vehicle fuelling is possible. The hydrogen purifier should be designed taking into account possible contamination from the hydrogen supply system or process equipment, such as oil in vapour or liquid form.

If adverse effects on the performance and/or corrosion are to be expected because of the quantity of moisture, the hydrogen gas should be dried such as to avoid water condensation at the highest pressure and in all operating conditions.

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1) The higher the velocity, the higher the vertically directed momentum and, thus, the lower the chance for the cross wind to bend the resulting flammable plume towards the ground. High momentum nature of the vertical release will ensure that the bulk of released gas is directed away from people and equipment.

2) The lower the velocity, the lower the horizontally directed momentum and, thus, the lower the horizontally projected footprint of the formed flammable plume. Buoyancy dominated nature of the horizontal release will ensure that the orientation of flammable plume will become vertical within a short proximity to the vent stack thus directing the bulk of released gas away from people and equipment. Cross wind in this case will help dispersion.

10 Electrical safety

10.1 General

10.1.1 Overview of electrical hazards

Clause 10 addresses electrical safety for hydrogen fuelling stations. There are many aspects to electrical safety in general and additional, specific aspects related to hydrogen and hydrogen fuelling. Some of the hazards common in electrical systems are:

— electric shock;

— electrical burns;

— arc flash / arc blast;

— fire;

— Electromagnetic interference (EMC).

Fuelling systems include many features and hazards common with many types of complex machinery including hazards due to:

— failure of control systems;

— operator error;

— etc.

Hydrogen fuelling systems in particular add this hazard:

— ignition of flammable atmospheres

The electrical system of the hydrogen fuelling station should be designed, installed, maintained, and serviced to eliminate these hazards where possible and minimize any that remain.

The electrical system of the hydrogen fuelling station should also be designed, installed, maintained, and serviced to eliminate any other electrical hazards identified in the risk assessment (see 5.1) where possible and minimize any that remain.

At a minimum the electrical system of the hydrogen fuelling station should comply with this clause, which is organized as follows:

— general electrical

  — components

  — equipment assemblies

  — site (interconnections to and/or between equipment assemblies)

  — lightning

— hazardous areas (potentially explosive atmospheres)

  — electrical equipment

  — other equipment

— Electromagnetic compatibility (EMC).

10.1.2 Components

Individual electrical components / devices or equipment assemblies that have any of the characteristics or are used in any of the ways listed below should comply with the requirements of the product safety standard(s) corresponding to that component device or assembly:

— connected to the electrical mains;

— contain, use, or are connected to hazardous voltage;

— perform a safety function.

Hazardous voltages are typically defined as greater than 50 VAC and 120 VDC in clean, dry conditions. However, much lower voltages can be hazardous in other conditions. The conditions of use should be considered when determining the hazardous voltage levels. See the SELV and PELV clauses of IEC 60364-4-41, and IEC 60204-1, for more information.

If there is no product safety standard(s) corresponding to a type of equipment, the equipment should conform to IEC 60204-1.

Valves, sensors, and other individual components or devices that are connected to the equipment assemblies should also conform to IEC 60204-1.

10.1.3 Site interconnections to and/or between equipment assemblies

Connections between the electrical equipment of the hydrogen fuelling stations and the electrical mains, or connections between electrical equipment assemblies of the hydrogen fuelling stations should also be designed, erected, installed, connected, tested, and verified in accordance with IEC 60364, Low-voltage electrical installations.

There are many clauses and sub-clauses to IEC 60364; the electrical equipment connections should comply with all clauses of IEC 60364 that apply.

NOTE 2 In many cases the requirements of IEC 60204-1 also apply to connections between electrical equipment assemblies of the hydrogen fuelling stations.

10.1.4 Electrical grounding

Hydrogen tanks, associated piping and systems should be earthed to prevent potential electrical shock.

NOTE IEC 60204-1 provides requirements for both protective and operational bonding.

The earthing system resistance should be less than 30 Ω.

Flanges should be electrically bonded. Electrical continuity across joints with an isolating seal (e.g. a polymer) should be ensured with electrical straps or similar. For example the 2 halves of flanged joints should be bonded together.

Enclosures where hydrogen is stored or used should be grounded.

Effectiveness of grounding connection should be verified at a frequency according to local regulation.

10.1.5 Lightning protection

Lightning protection should be provided in accordance with the IEC 62305 series of standards, i.e. IEC 62305-1, and the other parts of IEC 62305 appropriate for the type of equipment.

All hydrogen delivery vehicles should be electrically connected to the same earth ground as the fixed storage hardware prior to flexible hose connection.

10.2 Hazardous areas (potentially explosive atmospheres)

10.2.1 General

Hazardous areas, as classified according to IEC 60079-10-1, in which fixed electrical equipment should be appropriately classified, should be defined.

Hazardous areas are applicable from points of potential releases of hydrogen and/or other flammable fluids, or from the exhaust of natural or active ventilation of enclosures around equipment containing flammable fluids. Locations below the exhaust of ventilation of enclosures around hydrogen systems may be excluded.

A shelter or a canopy with a flat roof surface and with the sides sufficiently open to allow free passage of air through all parts should be considered well ventilated and should be treated as an outdoor area (i.e. "medium" degree and "good" availability). If the canopy is within the height of the classified area, the classified area should extend to the border of the canopy.

Where enclosures are placed around hydrogen equipment to contain and / or control hazardous areas, these should be in accordance with 5.6.3.

Area classification around venting system outlets should be defined on the basis of the specified maximum flow rate, considering also potential upset or accidental flow as defined in 9.14.5.

Hydrogen fuelling stations can include several hazardous areas, e.g. areas with potentially flammable or explosive atmospheres. The energy required to ignite a mixture of hydrogen and air is extremely small; see IEC 60079-20-1. Almost all electrical equipment can be an ignition source for a hydrogen / air mixture if proper protection is not implemented. In addition to the electrical circuits other aspects of the electrical installation or equipment can be ignition sources for hydrogen / air mixtures, for example:

— Rotating blades in fans;

— Hot surfaces;

— Electrostatic discharge from conductive parts or equipment to other conductive parts or earth.

Additional guidance on reducing the potential for the formation of explosive atmospheres included in 5.4.1 and 5.5.1.

10.2.2 Protection requirements for electrical equipment within hazardous (classified) areas

All electrical equipment in hazardous (classified) areas should be protected in accordance with the IEC 60079 series of standards, i.e. IEC 60079-0 and the appropriate other clause of IEC 60079 for the type of protection used. For example an intrinsically safe electrical system should comply with IEC 60079-0 and IEC 60079-11, and IEC 60079-25.

All electrical equipment in hazardous (classified) areas should be installed in accordance with IEC 60079-14.

Where new or existing electrical equipment is within the hazardous area surrounding hydrogen equipment, this should be rated for gas group IIC, or IIB+H2 hazardous areas. This is particularly relevant to integrated fuelling stations, where existing fuel dispensing equipment may not be rated for hydrogen. Further information is available in IEC 60079-14.

All electrical equipment installed in hazardous (classified) areas should be inspected and maintained in accordance with IEC 60079-17.

All electrical equipment installed in hazardous (classified) areas should be serviced, repaired, overhauled, and reclaimed in accordance with IEC 60079-19.

Mechanical parts of electrical equipment installed in hazardous (classified) areas should be protected in accordance with the ISO/IEC 80079 series of standards, i.e. ISO/IEC 80079-36, and the appropriate other clause of ISO/IEC 80079 for the type of protection used. For example a fan protected by construction should comply with ISO/IEC 80079-36 and ISO/IEC 80079-37.2.

10.2.3 Other equipment in hazardous (classified) areas

Mechanical equipment and mechanical parts of electrical equipment installed in hazardous (classified) areas should be protected in accordance with the ISO/IEC 80079- series of standards, i.e. ISO/IEC 80079-36, and the appropriate other clause of ISO/IEC 80079 for the type of protection used. For example a fan protected by construction should comply with ISO/IEC 80079-36 and ISO/IEC 80079-37.2.

10.2.4 Areas adjacent to hazardous areas

Flammable gases should be prevented from entering adjacent areas or compartments unless the equipment within the adjacent area or compartment is suitable for the resulting area classification.

Methods to prevent flammable gases from entering an adjacent area or compartment include but are not limited to:

— maintaining the adjacent area or compartment at a relative pressure higher than the area or compartment containing the flammable gas;

— sealing between areas / compartments;

— separation between the exhaust of one compartment and the intake of another compartment (allowance for ambient air dilution) (see 5.8.2.3).

NOTE One approach is to use negative pressure when ventilating an area containing a flammable gas.

When multiple purged hydrogen equipment enclosures are located in one area, the exhaust of ventilation from one hazardous area should not be introduced into adjacent enclosure compartments.

10.2.5 Protection from ignition due to accumulation of static charge

All exposed and extraneous conductive parts should be connected to the bonded grounding system in accordance with IEC 60079-14.

Development of electrical charges should be prevented by means ensuring both electrical continuity (throughout equipment and piping) and grounding.

To prevent the accumulation of static electricity in conductive equipment, the total resistance of the ground path to earth should be sufficient to dissipate charges that are otherwise likely to be present. The bonding system resistance should be less than or equal to 1 MΩ.

All sources that are able to cause static charges should be addressed, and measures should be taken to remove them completely or reduce the probability of their occurrence. At the design stage, the fuelling station should be examined to identify possible electrostatic hazards and the requirements of earthing should be determined.

WARNING — Electrostatic charges can occur when mechanical separation of similar or different substances takes place and also when a gas, containing droplets or dust particles, flow past the surface of a solid, e.g. valve openings, hose or pipe connections. If the accumulation of electric charges is released suddenly, the resulting electric spark can be sufficiently strong to ignite hydrogen.

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

Earthing devices should:

— either be clearly visible or be essential to the correct functioning of the fuelling station, so that any shortcomings are quickly detected;

— be robust and so installed that they are not affected by high resistive contamination, for example, by corrosion products or paint.

The use of non-conductive materials should be restricted in some hazardous areas.

In Zone 1 areas, non-conductive solid materials should only be used if charging mechanisms capable of generating hazardous potentials will not occur either during normal operation (including maintenance and cleaning) or in the case of likely malfunctions.

In Zone 2 areas, non-conductive solid materials should only be used if these do not generate electrostatic discharges.

10.3 Electromagnetic compatibility and interference (EMC)

10.3.1 General

Hydrogen fuelling stations should not emit electromagnetic noise that will interfere with other equipment at or near their sites and should not be adversely affected by electromagnetic noise at or near their sites.

The electrical equipment and systems of hydrogen fuelling stations should comply with the applicable parts of the IEC 61000 series of standards. These standards include:

— IEC PT 61000-3-1;

— IEC 61000-3-2;

— IEC 61000-3-3;

— IEC 61000-3-4;

— IEC 61000-3-5;

— IEC 61000-3-11;

— IEC 61000-3-12.

10.3.2 Industrial (EMC) environments

The electrical equipment and systems of hydrogen fuelling stations located in industrial environments should also comply with these IEC 61000 standards:

— IEC 61000-6-2;

— IEC 61000-6-4.

10.3.3 Residential, commercial, and light-industrial (EMC) environments

The electrical equipment and systems of hydrogen fuelling stations located in residential, commercial, or light-industrial environments should also comply with these IEC 61000 standards:

— IEC 61000-6-1;

— IEC 61000-6-3.

11 Markings

11.1 General

Warning signs, nameplates, markings, and identification plates should be of sufficient durability to withstand the physical environment involved including the effects of weather.

11.2 Warning signs

Fuelling station equipment assembly markings and warning signs should comply with the applicable clauses of ISO 3864, ISO 17398 and IEC 60417.

Warning signs should be placed to identify all hazards identified in the risk assessment of 5.1 including (but not limited to) the following types of hazards:

— flammable fluids;

— hazardous (classified) areas, where explosive atmospheres may exist;

— pressurized fluids;

— electrical hazards;

— contents from drain valves,

— hot or cold surfaces;

— mechanical hazards.

The following warning signs should be placed at all approaches to the fuelling station site:

— “Compressed Hydrogen”;

— “No smoking, open flames, or other ignition sources”;

— Hazardous areas, where applicable;

— “Authorized access only”.

Warning signs should be clearly displayed and visible at all times, particularly at access points, and should have black letters with a minimum height of 50 mm on a white or contrasted background. International symbols should be used where appropriate.

For liquid hydrogen installations, warning signs should indicate:

— LIQUID HYDROGEN;

— FLAMMABLE LIQUID;

— NO SMOKING;

— NO SOURCES OF IGNITION (NAKED FLAME);

— DO NOT SPRAY WATER ON VENT STACK;

— AUTHORIZED PERSONS ONLY.

For gaseous hydrogen installations, warning signs should indicate:

— GASEOUS HYDROGEN;

— FLAMMABLE GAS;

— COMPRESSED GAS;

— NO SMOKING;

— NO SOURCES OF IGNITION (NAKED FLAME);

— AUTHORIZED PERSONS ONLY.

For dispensing points, warning signs should be located within 3 m of the fuelling point, and should indicate:

— NO SMOKING;

— TURN IGNITION OFF DURING VEHICLE FUELLING;

— GASEOUS HYDROGEN;

— FLAMMABLE GAS;

Instructions for use of the dispenser by the general public should be included on or in the vicinity of / on each dispenser. These instructions should include prohibitions against:

— the use of adapters (e.g. 35 MPa vehicle filling from 70 MPa nozzle, or alternative fuel nozzles);

— the filling of undersized cylinder systems (whether in vehicle or not)

Sampling of hydrogen at the nozzle for quality purposes requires the filling of under-sized cylinders. This should be carried out only by trained persons according to a specific risk assessment and procedure.

11.3 Functional identification

Control devices, visual indicators, and displays (particularly those related to safety) should be clearly and durably marked with regard to their functions either on or adjacent to the item. Such markings may be as agreed between the user and the supplier of the equipment. Preference should be given to the use of standard symbols given in IEC 60417 and ISO 7000.

Fuelling assembly components should be marked according to 9.10.4.5.

Requirements for the marking of piping and tubing to identify content should be determined by risk assessment and be implemented according to national requirements. As a minimum, it is recommended that the pipes accessible to the public, or visible by the public, should be marked.

NOTE ASME A13.1 documents one scheme for the identification of piping systems.

11.4 Marking of equipment (data plate)

Each fuelling station major supplied assembly should bear a data plate or combination of adjacent labels located so as to be easily read when the equipment is in a normally installed position.

Where an IEC or ISO product safety standard exists for the equipment it should be marked in accordance with that standard.

Where an IEC or ISO product safety standard does not exists for the equipment the data plate/label(s) should include the following information as applicable:

a) manufacturer’s name, trademark and location;

b) the model number or type;

c) serial number;

d) date of construction;

e) utility connections (as applicable);

- electrical:
  - electrical input range in volts;
  - current rating in amperes;
  - frequency in hertz and number of phases;
  - rated nominal power input (watts or VA);
- fuel:
  - type;
  - quality;
  - pressure range;
  - flow rate (consumption);
  - rated nominal thermal input;

f) environmental ratings:

- IP rating;
- ambient temperature range;
- if applicable, the area classification rating;

g) hydrogen output

- pressure range in MPa;
- temperature range of output hydrogen in °C;

h) main document number (see IEC 62023).

Equipment designed to be used in hazardous (classified) areas should be marked as required by IEC 60079-0 and the appropriate parts of IEC 60079 for the type(s) of protection used.

11.5 Reference designations

All enclosures, assemblies, control devices, and components should be plainly identified with the same reference designation as shown in the technical documentation.

11.6 Emergency contact information

In order to facilitate control of an emergency, a sign with the following emergency contact information should be included at the fuelling station site:

- the station operator's name and local address;
- the station operator's local phone number;
- the phone number of the local emergency service.

Operating, maintenance and emergency instructions should be supplied to the fuelling station owner before commissioning the installation.

12 Technical documentation

12.1 General

The information necessary for installation, operation, and maintenance of the hydrogen fuelling station equipment should be supplied in the appropriate forms, for example, drawings, diagrams, charts, tables, instructions. The information should be in an agreed language. The information provided may vary with the complexity of the equipment. For very simple equipment, the relevant information may be contained in one document, provided that the document shows all the devices of the equipment and enables the connections to the utilities to be made.

NOTE 1 The technical documentation provided with items of electrical equipment can form part of the documentation of the hydrogen fuelling station equipment.

NOTE 2 In some countries, the requirement to use specific language(s) is covered by legal requirements.

12.2 Information to be provided

The information provided with the hydrogen fuelling station equipment should include:

a) A main document (parts list or list of documents);

b) Complementary documents including:

   1) a clear, comprehensive description of the equipment, installation and mounting, and the connection to the electrical supply(ies) and other utilities;

   2) electrical supply(ies) and other utility requirements;

   3) information on the physical environment (for example lighting, vibration, atmospheric contaminants) where appropriate;

   4) overview (block) diagram(s) where appropriate;

   5) circuit diagram(s);

   6) information (as applicable) on:

   — programming, as necessary for use of the equipment;

   — sequence of operation(s);

   — frequency of inspection;

   — frequency and method of functional testing;

   — guidance on the adjustment, maintenance, and repair, particularly of the protective devices and circuits;

   — recommended spare parts list; and

   — list of tools supplied.

7) a description (including interconnection diagrams) of the safeguards, interlocking functions, and interlocking of guards against hazards, particularly for equipment operating in a coordinated manner;

8) a description of the safeguarding and of the means provided where it is necessary to suspend the safeguarding (for example for setting or maintenance), (see 10.2.5);

9) instructions on the procedures for securing the hydrogen fuelling station for safe maintenance; (see also 12.10);

10) information on handling, transportation and storage;

11) information regarding load currents, peak starting currents and permitted voltage drops, as applicable;

12) information on the residual risks due to the protection measures adopted, indication of whether any particular training is required and specification of any necessary personal protective equipment;

13) emergency contact information;

14) cause and effect matrix summary, including description of safety loop and critical equipment.

12.3 Recommendations applicable to all documentation

Unless otherwise agreed between manufacturer and fuelling station owner or operator:

— the documentation for the electrical system should be in accordance with relevant parts of IEC 61082;

— reference designations should be in accordance with relevant parts of IEC 61346;

— instructions/manuals should be in accordance with IEC 82079-1.

— parts lists where provided should be in accordance with IEC 62027, class B.

NOTE See item 13 of Annex B.

For referencing of the different documents, the supplier should select one of the following methods:

— where the documentation consists of a small number of documents (for example less than 5) each of the documents should carry as a cross-reference the document numbers of all other documents belonging to the hydrogen fuelling station equipment; or

— for single level main documents only (see IEC 62023), all documents should be listed with document numbers and titles in a drawing or document list; or

— all documents of a certain level (see IEC 62023) of the document structure should be listed, with document numbers and titles, in a parts list belonging to the same level.

12.4 Installation documents

12.4.1 General

The installation documents should give all information necessary for the preliminary work of setting up the hydrogen fuelling station equipment (including commissioning). In complex cases, it may be necessary to refer to the assembly drawings for details.

The recommended position, type, and cross-sectional areas of the supply cables to be installed on site should be clearly indicated. The data necessary for choosing the type, characteristics, rated currents, and setting of the overcurrent protective device(s) for the supply conductors to the electrical equipment of the machine should be stated (see 7.2.2 of IEC 60204-1, Supply conductors).

Where necessary, the size, purpose, and location of any ducts in the foundation that are to be provided by the user should be detailed.

The size, type, and purpose of ducts, cable trays, or cable supports between the machine and the associated equipment that are to be provided by the user should be detailed.

Where necessary, the diagram should indicate where space is required for the removal or servicing of the hydrogen fuelling station equipment.

NOTE 1 Examples of installation diagrams can be found in IEC 61082-4.

In addition, where it is appropriate, an interconnection diagram or table should be provided. That diagram or table should give full information about all external connections. Where the electrical equipment is intended to be operated from more than one source of electrical supply, the interconnection diagram or table should indicate the modifications or interconnections required for the use of each supply.

NOTE 2 Examples of interconnection diagrams/tables can be found in IEC 61082-3.

The installation documentation should also include guidelines on:

— equipment unpacking;

— location and design of the foundation;

— installation and interconnection;

— ventilation recommendations;

— protection from weather hazards;

— recommended height in relation to the base flood elevation;

— altitude;

— security enclosure;

— acceptable distances from exposures; and

— protection from vehicular impact.

The installation documentation should define the services and utilities, for example drains and waste water required for operation of the hydrogen fuelling station.

12.4.2 Installation documentation for hazardous (classified) areas

The hydrogen fuelling station installation documentation should indicate the area classification (zone) and extent of any hazardous (classified) areas, see 5.5.2, Area classification.

The installation documentation should also include specific instructions for the proper installation of hydrogen fuelling station equipment that is designed to be installed in classified areas in order to ensure compliance with IEC 60079-0 and with any other parts of IEC 60079 used for protection; see especially IEC 60079-14.

The installation documentation for hydrogen fuelling station components and assemblies using active ventilation as a means to protect against the accumulation of ignitable mixtures in accordance with 5.5 should also include recommendations for:

— source of ventilation air;

— location of exhaust;

— ducting (when used);

12.4.3 Venting

The installation documentation should provide guidelines for the proper venting of gases and the proper installation of the vent lines. The installation documentation should indicate that relieved gases should be vented to a safe area

12.4.4 Seismic documentation

The seismic rating, should be included in the installation documentation.

12.4.5 Handling and lifting documentation

Instructions on how to safely handle and lift hydrogen fuelling station assemblies should be provided.

Lifting point to facilitate lifting by crane, forklift or other means as may be appropriate for the size and weight of the hydrogen fuelling station assembly should be provided and identified.

12.5 Overview diagrams and function diagrams

Where it is necessary to facilitate the understanding of the principles of operation, an overview diagram should be provided. An overview diagram symbolically represents the hydrogen fuelling station equipment together with its functional interrelationships without necessarily showing all of the interconnections.

NOTE 1 Examples of overview diagrams can be found in IEC 61082 series.

Function diagrams may be provided as either part of, or in addition to, the overview diagram.

NOTE 2 Examples of function diagrams can be found in IEC 61082-2.

12.6 Circuit diagrams

A circuit diagram(s) should be provided. This diagram(s) should show the electrical circuits on the hydrogen fuelling station and its associated electrical equipment. Any graphical symbol not shown in IEC 60617 should be separately shown and described on the diagrams or supporting documents. The symbols and identification of components and devices should be consistent throughout all documents and on the hydrogen fuelling station.

Where appropriate, a diagram showing the terminals for interface connections should be provided. That diagram may be used in conjunction with the circuit diagram(s) for simplification. The diagram should contain a reference to the detailed circuit diagram of each unit shown.

Switch symbols should be shown on the electromechanical diagrams with all supplies turned off (for example electricity, air, water, lubricant) and with the machine and its electrical equipment ready for a normal start.

Conductors should be identified in accordance with 13.2 of IEC 60204-1.

Circuits should be shown in such a way as to facilitate the understanding of their function as well as maintenance and fault location. Characteristics relating to the function of the control devices and components which are not evident from their symbolic representation should be included on the diagrams adjacent to the symbol or referenced to a footnote.

12.7 Flow (P&ID) diagrams

A flow diagram(s) should be provided. This diagram(s) should show the fluid piping on the hydrogen fuelling station and its associated instruments, valves, and equipment in accordance with ISO 10628-1. Any graphical symbol not shown in ISO 10628-2 or ISO 14617 should be separately shown and described on the diagrams or supporting documents. The symbols and identification of components and devices should be consistent throughout all documents and on the hydrogen fuelling station.

Where appropriate, a diagram showing the interface connections should be provided. That diagram may be used in conjunction with the flow diagram(s) for simplification. The diagram should contain a reference to the detailed flow of each unit shown.

Valve symbols should be shown on the flow diagrams with all supplies turned off (for example electricity, air, water, lubricant) and with the hydrogen fuelling station and its fluids equipment ready for a normal start.

Piping and circuits should be shown in such a way as to facilitate the understanding of their function as well as maintenance and fault location. Characteristics relating to the function of the control devices and components which are not evident from their symbolic representation should be included on the diagrams adjacent to the symbol or referenced to a footnote.

12.8 Fuelling station operating manual

The technical documentation should contain an operating manual detailing proper procedures for set-up and use of the hydrogen fuelling station equipment. Particular attention should be given to the safety measures provided.

The operating manual should indicate the hazards related to the use of the fuelling station.

The operating manual should also include a description and explanation of all warnings and markings on the hydrogen fuelling station especially those relating to hazardous (classified) areas.

12.9 Hydrogen fuelling station dispenser operation instructions

Hydrogen fuelling station dispenser operation instructions for dispensing hydrogen into a vehicle may be displayed as markings or electronic displays at the dispenser.

12.10 Maintenance manual

The technical documentation should contain a maintenance manual detailing proper procedures for adjustment, preventive inspection, and replacement of consumables by the end user. Recommendations on maintenance intervals and records should be part of that manual.

This manual should contain clearly defined, legible and complete instructions for starting, shutting down and servicing the hydrogen fuelling station.

The maintenance instructions should also include specific instructions for the proper maintenance of the hydrogen fuelling station designed to be installed in classified areas to ensure compliance with IEC 60079-0 and with any other parts of IEC 60079 used for protection in accordance with IEC 60079-17.

12.11 Service manual

The technical documentation should contain a service manual detailing proper procedures for adjustment, servicing and preventive inspection, and repair. Recommendations on maintenance/service intervals and records should be part of that manual. Where methods for the verification of proper operation are provided (for example software testing programs), the use of those methods should be detailed.

Where the operation of the equipment can be programmed, detailed information on methods of programming, equipment required, program verification, and additional safety procedures (where required) should be provided.

If the hydrogen fuelling station is provided with the capability for remote monitoring / data transmission, remote operation, or remote control code modifications, see 6.4, the station manufacturer or integrator should supply the instructions / procedures for the operator to be able to monitor the station remotely, receive data from the station, and/or to permit fuelling from an unattended station.

NOTE The service manual is not required to be provided to the end user unless the end user is expected to perform service on the hydrogen fuelling station equipment.

12.12 Parts list

The parts list, where provided, should comprise, as a minimum, information necessary for ordering spare or replacement parts (for example components, devices, software, test equipment, technical documentation) required for preventive or corrective maintenance including those that are recommended to be carried in stock by the user of the equipment.

12.13 Technical file

It is recommended that the manufacturer and/or integrator assemble the documentation for the hydrogen fuelling station components, subsystems, assembly compliances, intended installation environment, and maintenance and service requirements into a technical file. This technical file should be kept according to applicable national regulations and laws after the hydrogen fuelling station is decommissioned, disassembled, and disposed of.

The technical file should include the following minimum documentation:

— risk assessment;

— declarations of conformity / manufacturer's declarations;

— manuals;

— technical specifications;

— component lists;

— schematics and technical diagrams;

— assembly and layout drawings;

— calibration certificates.

13 Station inspection and tests

13.1 General

The hydrogen fuelling station should be inspected and tested to validate compliance with the recommendations of this Technical Specification and local requirements. All inspection and test results should be retained according to local requirements.

The hydrogen fuelling station installation and documentation should pass minimum acceptance inspection before safety and performance validation tests are conducted.

The hydrogen fuelling station should pass minimum on-site safety tests to validate compliance with this Technical Standard before performance tests are conducted. The hydrogen fuelling station should pass minimum on-site performance tests before normal vehicular fuelling is allowed.

The hydrogen fuelling station should pass minimum periodic re-inspection, periodic safety re-test, and periodic performance re-test to assure continued compliance with this Technical Standard and to permit continued fuelling operation.

To avoid unnecessary duplication of work, previously certified parts and components (for example, pressure assemblies or equipment, etc.) should not need to be retested during the initial inspection of the fuelling station. Wherever retesting of components or assemblies is necessary after the start of operation, this should be performed accordingly. When necessary according to national requirements, the appropriate safety documents for the hydrogen fuelling station should be checked and verified by an authority or third party with consideration of the location the environment and the interdependency to neighbouring systems.

13.2 Minimum hydrogen fuelling station acceptance inspection

13.2.1 General

The entire hydrogen fuelling station should be installed in accordance with the manufacturer's instructions, any certification/approval requirements, the recommendations of this Technical Specification, and local requirements.

Minimum inspection of the hydrogen fuelling station for compliance to site-specific operational and environmental requirements, local requirements, and this Technical Specification should include:

- site plans;
- physical installation;
- verification of good housekeeping;
- individual subsystems;
- subsystem integration;
- safeguarding process:
  - safety measures according to the global safety concept;
  - installations in hazardous areas (see 10.2.1);
- operational procedures;
- maintenance procedures and maintenance record format;
- component marking, technical file, and documentation of Clauses 11 and 12;
- verification of emergency communication.
- confirmation of existence of calibrated redundant temperature and pressure sensors (where applicable) for hydrogen gas and ambient temperature sensor.

At a minimum, the checklist of Table 5 should be used by authorities to guide fuelling station acceptance inspection to the recommendations of this Technical Specification.

13.2.2 Minimum hydrogen fuelling station acceptance testing

The entire hydrogen fuelling station should be tested within the manufacturer specified capacity, usage, voltage, frequency, gas and liquid pressures, temperature, and altitude.

If there are some specific requirements from the regulatory authority, this should be considered in the acceptance test as well.

At a minimum, the checklist of Table should be used to guide hydrogen fuelling station acceptance testing.

Minimum acceptance testing should include:

- electrical grounding and bonding testing, according to 5.5.1 and 10.1.4;
- fuelling pad resistance, according to 9.10.2;
- pressure and leak integrity of subsystem piping interconnections, defined further in 13.2.3 and 13.2.4;
- safety function control and alarms according to Clause 6:
  - fire and combustible gas detection systems;

  - emergency shut-off systems;
  - emergency shutdown of hydrogen fuelling station equipment according to 5.4.3, 5.7.6, 6.2, 6.3, 8.2.2, 9.10.3.2 and Clause 10;
- testing to ensure fuelling does not exceed the limits according to 8.2.1, 8.2.2.2 and 8.2.2.4.1 and the station terminates the fuelling within 5 seconds if these limits are exceeded;
- fuelling protocol testing according to 13.2.7.1 and Annex B;
- hydrogen quality testing according to 8.3.

13.2.3 Pressure test

The strength and integrity of all pressure bearing parts, including joints and connections, that convey a fluid should be pressure tested using either hydraulic means or pneumatic means, in accordance with applicable national regulations.

No permanent deformation or mechanical failure should be allowed.

Individual components or assemblies provided with manufacturer's certification of pressure test do not need to be subjected to the complete system pressure test(s) where the components or assemblies can be isolated or removed from the pressure systems for the test(s). Connection points of such subsystems to the fuelling station should be pressure tested. Means of pressure indication suitable for the test pressure should be installed before the test. Precautions should be taken to prevent excessive pressure in the system during the test. Following any hydraulic test of a pneumatic system, the system/equipment should be drained and thoroughly dried out and checked.

Where a pneumatic test is specified, the pressure in the system should be increased gradually up to the test pressure. Any defects found during the test should be rectified in an approved manner.

Testing should be repeated until satisfactory results are obtained.

A suitable pressure test certificate should be signed and issued. Records of pressure tests and certificates should be maintained and filed for future reference.

Pressure relief valves and other pressure sensitive instruments may be removed for the test and lines capped.

The pressure test(s) may be carried out either prior to delivery to the site, or on the site where the fuelling station is to be installed, however pressure testing prior to delivery to the site is recommended where possible, to minimise contamination from test fluids during on-site pressure testing. Hydraulic pressure test(s), when required, should be carried out on subsystems prior to delivery to the site where the fuelling station is to be installed, where it is easier to manage the removal of contamination than with on-site testing, in order to minimize the efforts needed to remove contamination from test fluids used.

If a pneumatic test is used, nitrogen, helium, or non-flammable hydrogen mix, is recommended.

High pressure hydrogen gas is much more hydroscopic than dry nitrogen and is the most effective cleaning agent for hydrogen piping and storage. Purging the fuelling station components with high quality hydrogen after replacement or atmospheric contamination of hydrogen pressure rated components is recommended to meet the recommendation of 8.3.

13.2.4 Leak test

The integrity of all pressure bearing hydrogen systems in the fuelling station should be verified by measuring the ability of the system to retain hydrogen at normal operating pressure when isolated from the supply of hydrogen or other means.

When and where possible, it is recommended to use a pressure drop test. When the test pressure is reached, the flow of test gas should be stopped and the pressure in the test subsection should be monitored for at least 2 min. for systems with a small volume (e.g. less than 15 l). For larger volumes an adequate time to be monitored should be determined and agreed by a third party inspection, where applicable. There should be no measurable pressure drop or observable leakage of test gas.

A leak test should be conducted on hydrogen subsystems, on the interconnections and on the whole system. The leak test should follow the pressure test. Depending on the complexity, the leak test may be executed sub-system by sub-system or for all the sub-systems at the same time, when the whole assembly has been connected and prepared for commissioning.

Care should be exercised in selection of a non-contaminating test gas in accordance with manufacturer's instructions and safety of operations. Care should be exercised to remove air from hydrogen systems prior to introduction of hydrogen.

The leak test pressure should be no less than the maximum normal operating pressure for each subsection of the fuelling station system.

Alternately, hydrogen subsystems and interconnections may be leak tested using a helium detector with a mixture composed of dry nitrogen and a minimum volume fraction of 5 % helium, ora hydrogen detector with a mixture composed of dry nitrogen and a maximum volume fraction of 5 % hydrogen. The results of measurements should be transferred by calculation into equivalent hydrogen leakage rates.

Leak testing should be repeated until satisfactory results are obtained with the hydrogen station system assembled in final configuration (and pressure tested with hydrogen).

All nitrogen should be vented from the field-installed subsystems, the entire fuelling station system assembled in final configuration with all subsystems and components reinstalled (if removed for pressure testing) and the entire system purged with high purity hydrogen. The final leak testing should be conducted with hydrogen at increasing pressures up to maximum system operating pressures (of each section of the stations system) once the entire system is completely assembled.

Hydrogen leaks may detected on components or fittings on fully assembled and pressurized or operating systems using an approved hand held hydrogen gas leak detector. The leak test(s) should be repeated after any subsystem repairs, and periodically, according to manufacturer's instructions.

13.2.5 Electrical testing

Electrical verification testing in accordance with Clause 18 of IEC 60204-1 should be performed on the hydrogen fuelling station. This testing should include:

— Verification of conditions for protection by automatic disconnection of supply (typically a "ground / bond test");

— Insulation resistance tests;

— Voltage tests;

— Protection against residual voltages;

— Functional tests which are safety related mitigation measures (see Clause 6).

Functional testing especially of the safety circuit(s) should be thorough, complete, and unambiguous. All inputs should be activated or simulated individually. Each device in the circuit or system should be checked individually for each input activation or simulation. Care should be taken to ensure that only the circuit under test caused the required action. Careful inspection and disconnection of other devices, circuits, or systems may be required to eliminate paths other than the one under test (ex. "sneak circuits").

Where a portion of the fuelling station and its associated equipment is changed or modified, that portion should be re-verified and retested, as appropriate (IEC 60204-1, 18.1).

Particular attention should be given to the possible adverse effects that retesting can have on the equipment (for example overstressing of insulation, disconnection/reconnection of devices).

13.2.6 Communications test

All hydrogen dispensers with communications should implement a vehicle to dispenser communication system that meets the specifications of the fuelling protocol, such as SAE J2799 and SAE J2601.

13.2.7 Safety and performance functional testing of the hydrogen fueling station

13.2.7.1 General

Testing verifies that the hydrogen fuelling station meets the manufacturer's specification and the recommendations of Clause 8.

13.2.7.2 Fuelling protocol test

13.2.7.2.1 General

The fuelling protocol test should be tested at each dispenser nozzle to confirm that the dispenser is using an approved fuelling protocol, such as SAE J2601, to control the rate of fill, the fuel temperature, and the target pressure, etc. Safety related fuelling process limits and performance targets should be evaluated.

Testing capability should include a data acquisition system and ability to test the vehicle-to-dispenser communication system. This assumes that access to pressure and temperature signals of the dispenser or data from the station owner / operator / manufacturer, as applicable, during testing will be given for the station acceptance testing.

NOTE Annex B offers an example of acceptance testing for stations that utilise the SAE J2601 fuelling protocol.

13.2.7.2.2 Test apparatus

Hydrogen fuelling stations should be tested at each dispenser nozzle using a Hydrogen Station Test Apparatus (HSTA) that is representative of the size(s) of vehicle fuel storage systems that will be using the dispenser (wherever possible according to capability of the HSTA).

NOTE Annex B offers examples of hydrogen station test apparatus that could be used for Acceptance Testing for stations that utilise the SAE J2601 fuelling protocol.

13.2.7.2.3 Test procedure

Stations should be validated by testing to ensure that they meet the following recommendations:

1) The station terminates the fuelling within 5 seconds if the safety and performance process limits for all fuelling protocols, as listed in 8.1.3, (or, for example, Clauses 7 and 9 of SAE J2601) are exceeded;

2) The station implements the fuelling protocol being used, correctly (e.g., Table-based Fuelling Protocol, listed in Clause 9 of SAE J2601);

3) The station implements the SAE J2799 or intended vehicle to station fuelling communication protocol correctly and terminates the fuelling within 5 seconds upon receiving an abort signal or if an incorrect signal is sent to the station.

NOTE Refer to Annex B for an example of a table-based test procedure.

13.2.7.3 General hydrogen quality testing requirements

13.2.7.3.1 Hydrogen quality test

At first commissioning, periodically, and after maintenance procedures that may impact hydrogen quality, the hydrogen should be sampled at the dispenser to determine the impurity levels and ensure compliance with ISO 14687-2 fuel cell grade impurity threshold limits, according to 8.3.

Gas phase impurities in the dispensed hydrogen may be captured with a sampling adapter and taken off site for laboratory analysis. A representative sample from multiple fuelling station hydrogen storage banks should be taken to confirm that all storage banks have been cleaned and purged properly to assure compliance with ISO 14687-2 fuel cell grade impurity threshold limits.

In addition to gas phase contaminants, the dispenser should be tested for particulates with a suitable adapter and test method, such as ASTM D7650 or ASTM D7651.

13.2.7.3.2 Hydrogen quality test apparatus

The Hydrogen Quality test apparatus should connect to the dispenser nozzle. The test apparatus should use the ASTM D7606, ASTM D7650, ASTM D7651 test standards, or equivalent.

13.2.7.3.3 Hydrogen quality test procedure

When testing for compliance with impurity threshold limits, as defined in 8.3, the sampling system should be connected to the dispenser nozzle and used to fill a test tank for analysis.

The evaluation of particulate entrained in the fuel and included in the dispenser flow should be measured using a suitable adapter and test method, such as ASTM D7651.

13.3 Minimum periodic hydrogen fuelling station inspection and test

At a minimum, the checklists of Tables 6, 7 and 8 should be used by authorities to guide hydrogen fuelling station periodic inspection and testing.

The fuelling station maintenance record should be made available for inspection by authorities having jurisdiction.

Repair or direct replacement of fuelling station components should require verification and validation as applicable, according to 13.2.

Table 6 — Minimum hydrogen fuelling station acceptance inspection checklist

Minimum fuelling station acceptance inspection checklist				
Name and address of the operator:				
Name and address of the constructor:				
Place and address of the designated operation site:				
Date:				
Inspection by:				
No.	**Content /requirement**	**Reference to ISO/TS 19880-1 (clause)**	**Pass/fail**	**Link to other standards/remarks**
-	**Design documentation**	-	-	-
	Permit for construction/installation	Per local authority		e.g. BetrSichV in Germany
	Safety concept / description	12.2		

Table 6 *(continued)*

Minimum fuelling station acceptance inspection checklist				
	- safety devices / safeguarding process (mechanical, PLC etc.)	6, 8.2.2, 7.2.2, 9.4.3, 9.6		Set pressure of safety valves, wiring diagram, logic diagram etc. for PLC
	- explosion protection document / zones	5.5.2, 12.4.2		
	- protective measures to avoid building of a hazardous atmosphere	5.4		e.g. ventilation system, gas sensor, etc.
	- Safety distances	5.2.1.1, 5.8		Per national code
	Hazard and risk analysis	5.2		PED / national / local requirements
	Civil work – structural	Per local authority		Per national/local authority
	Document of Conformity, certifications	12.13		PED, EMC, ATEX, Machinery Applicable certifications (ASME B31, B&PVC, NF PA2 10.3)
	Design examination for pressure equipment	9		PED, ASME, etc.; CE-marking in Europe, DoC or manufacturer declaration
	- pressure vessel / storage	9.3.1		
	- piping / hose	9.1.3, 9.10		
	- components	9		
	- pumps / compressor	9.4, 9.5		ISO 24490
	- pressure relief valves	7.2.2.5, 9.4.3, 9.6		ISO 4126; ISO 21013, ASME B&PVC,
	- dispenser	8, 8.2.2, 9.10.3		CSA-HGV 4.3
	- assembly / sub-assembly	7.1, 9.10.4		e.g. water electrolyser ISO 22734-1, etc.
	System pressure test / leakage test	13		Manufacturer test documentation
	Design examination for electrical equipment	6.2, 10.2.2		ATEX, NFPA 70(NEC)
	Vehicle compliant fuelling protocol	8.2.1		Dispenser manufacturer documentation
-	**Manuals, diagrams, and instructions**	-	-	-
	Dispenser operation instructions	12.2(4)		
	Station operation manual	12.2(5)		
	Flow diagrams (P&ID or PFD)	12.7		ISO 10628-1
	Wiring diagrams	12.2(6)		13.2 of IEC 60204-1,
	Installation instructions	12.2(7)		
	Station maintenance manual	12.2(8)		Manufacturer determines periodic inspection intervals by the operator
	Maintenance log	12.2(8)		

Table 6 *(continued)*

Minimum fuelling station acceptance inspection checklist				
-	**Physical Installation**	-	-	-
	Compliant with manufacturer's instructions	9, 13.2		Per manufacturer's instructions
	Layout	5.7.2		IEC 61082 series
	Piping	9		ISO 15649:2001; EN 13480 part 1 to 8
	Wiring (especially protective bonding)	10		IEC 60204-1; IEC 60364
	Protection from vehicular impact	5.7.4, 9.10.1		
	Fire barriers	5.7.3		
	Fire fighting equipment	5.7.4, 5.7.5		Per local authority
	Separation distances	5.8		Per national code
	Equipment enclosures	5.4.4, 5.6.3, 5.9.1, 5.9.2, 5.9.3		Consider personnel egress and asphyxiation, environment protection, Mixture mitigation
	Personnel access, egress and emergency equipment access	5.7.5		Authorized access, emergency escape
	Flammable gas vent	5.4.5		
	Markings	11		ISO 3864, ISO 17398 and IEC 60417
	Markings are permanent	11.1		
	Piping and tubing	9.2, 11.3		ASME A13.1
	Vents	9.1.4, 11.3		CGA G-5.5
	Control devices/indicators/displays	11.3		IEC 60417 and ISO 7000
	Warning Signs	11.2		
	Equipment Data plates/label	12.4		IEC 62023, IEC 60079-0
	Fuelling hose assembly	9.11		
	Emergency stop	5.4.3, 5.7.6, 6.2, 6.3, 8.2.2, 9.11.1, 11.4		ISO 13850, IEC 60204-1
	Emergency contact	11.6		operator, gas supplier

Table 7 — Minimum on-site hydrogen fuelling station acceptance test checklist

Minimum on site fuelling station acceptance test checklist					
Name and address of the operator:					
Name and address of the constructor:					
Place and address of the designated operation site:					
Date:					
Inspection by:					
No.	**Content/requirement**	**Requirement value**	**Reference to ISO/TS 19880-1 (clause)**	**Pass/fail**	**Link to other standards / remarks**
	Electrical bonding and grounding, components to earth	≤ 30 Ω	13.2.5, 10.1.4		IEC 60204-1 Clause 18
	Insulation resistance	≥ 1 MΩ	13.2.5		IEC 60204-1 Clause 18
	Voltage test	per applicable standard	13.2.5, 10.1.2		IEC 60204-1 Clause 18
	Protection against residual voltages	per applicable standard	13.2.5, 10.1.2		IEC 60204-1 Clause 18
	Fuelling pad resistance	1 MΩ	9.10.2, 10.2.4		IEC 60079-14
	Pressure test	Per national regulations	13.2.3		Per national regulations
	Leak test	Per national regulations	13.2.4		Per national regulations
	Dispensed Hydrogen Quality test	ISO 14687-2,	13.2.7.2.3, 8.3		ASTM D7606, ASTM D7650, ASTM D7651
	Dispenser communications	SAE J2799	8.2.2.4, 13.2.7.2.3		SAE J 2799 and SAE J 2601
	Dispenser fuelling limit test	Per applicable standard	13.2.7.2.3 (1,2) 8.2.2.2		SAE J2601
	Dispenser fuelling protocol	Per applicable standard	13.2.7.2.3 (3) 8		SAE J2601
	Verify emergency and safety functions	100 %	5.4, 5.5.1, 5.5.2, 5.7.6, 6.2, 6.3, 8.2.3, 9.10.3.2 and Clause 10, 12.8, 13.2.5		See Notes in 13.2.5
	Verify Emergency communication according to the risk assessment.	100 %	13.2		Test communications with emergency responders

Table 8 — Minimum periodic hydrogen fuelling station inspection and test checklist

Minimum periodic fuelling station inspection and test checklist					
Name and address of the operator:					
Name and address of the constructor:					
Place and address of the designated operation site:					
Date:					
Inspection by:					
No.	**Content/requirement**	**Requirement value**	**Reference to ISO/TS 19880-1 (clause)**	**Pass/fail**	**Link to other standards/ remarks**
	Safe work permit		5.5.2		Per local authority (grinding/welding)
	Good housekeeping		13.2.1		
	Maintenance log up to date		13.3		
	- sensor calibration				
	- leakage test				
	- PRV within calibration date				
	- Hose within date				
	Dispensed Hydrogen Quality test report	ISO 14687-2	13.2.7.2.1, 8.3		ISO 14687-2
	Dispenser communications	Per applicable standard	13.2.7.2.3(3) 8.2.2.4		SAE J 2799 and SAE J 2601
	Dispenser fuelling limit test	Per applicable standard	13.2.7.2.3(1,2) 8.2.2.2		SAE J2601
	Dispenser fuelling protocol	Per applicable standard	13.2.7.2.3(2) 8		SAE J2601
	Verify emergency and safety functions	100%	5.3, 5.4.2, 5.4.3, 12.8, 13.2.2		See Notes in 13.2.5
	Verify Emergency communication according to the risk assessment.	100%	13.2.1		Test communications with emergency responders

Annex A
(informative)

Safety distances definition and basic principles

A.1 Safety distance toolkits

Toolkits can be used to facilitate implementation of the methodology.

An approved toolkit should:

— contain the latest available data and models (ideally, validated for hydrogen infrastructure use) relevant to quantifying the probability of progression various hazard scenarios;

— contain the latest available data and models (ideally, validated for hydrogen infrastructure use) relevant to prediction of physical properties of hydrogen releases and ignition events, and the consequences of those events;

— calculate the representative observable quantities (e.g., physical parameters, damages, number of fatalities) relevant to decision making for safety, codes, and standards;

— facilitate relative risk comparison, sensitivity analysis, and treatment of uncertainty;

— provide default models, values and assumptions, and provide transparency about those defaults; furthermore, it allows modification of these defaults to reflect different systems and new knowledge.

A.2 Example of toolkit: HyRAM

This is a toolkit for integrated deterministic and probabilistic risk assessment for hydrogen infrastructure.

A.3 Example safety distances from each country / region

The following is a table of examples of safety distances collected by ISO/TC 197, through country representative members. This table is meant to convey a status of country specific safety distances and the wide range of results but it is not an inclusive list of values internationally.

NOTE 1 Table A.1 is not meant to be a recommendation for these applications and could be subject to change from local standards and codes and this list could be revised in future versions. Units are in meters unless otherwise noted. It is intended in the future ISO 19880-1 that a quantitative risk assessment example be included in an informative Annex to help with alternative methods for determining appropriate safety distances.

Table A.1 — Examples of hydrogen fuelling station safety distances currently in use globally

			CA	CN	FR	DE	IT	JP	KR	SE	UK	US
RESTRICTION DISTANCES *The restriction distance is the minimum distance from, or area around, hydrogen equipment where certain activities are restricted or subject to special precautions*	Potential area of flammable / explosive atmosphere round compression unit	m				IEC 60079-10		8	8		5	0 to 4,6 m Class1 Div2
	Potential area of flammable / explosive atmosphere around storage unit	m						8	8		5	0 to 4,6 m Class1 Div2
	Potential area of flammable / explosive atmosphere around dispenser	m		4,5				0,6			-	0 to 1,5 m Class1 Div2
	Sparking equipment, open flames, welding	m	7,6	20-40				8	8		5	10,7
	Outdoor discharge for relief valves or vents	m		3-10							-	1,5 m Div1 4,6 m Div2
INSTALLATION LAYOUT DISTANCES *The installation layout distance is the minimum distance between the various units of the main equipment of the hydrogen installation required to prevent units causing damage to one another in case of incidents.*	Between Sub-System / Equipment of any kind	m		3-15		1 m vessels without opening 0,5 m				1	-	
	Between H2 Storage and other Sub-System / Equipment	m		3-15					Max [1, (radius 1+ radius 2)/2]		-	
	Between Compressor and other Sub-System / Equipment	m		3-9							-	
	Between Equipment and barriers around the plant (access and circulation)	m		2-5 (walls)							0,6	
	Between hydrogen dispenser and other non hydrogen equipment except vehicle	m				2					-	

Table A.1 *(continued)*

			CA	CN	FR	DE	IT	JP	KR	SE	UK	US
PROTECTION DISTANCES *The protection distance is the minimum distance required between the installation/equipment to be protected of the possible source of an external hazard (e.g. a fire) to prevent damage.*	Presence of (liquid) combustibles above ground (like gasoline storage or a tank truck)	m	7,6 to 15,2	18-35		5			8	50	8	
	Private or public road (Collision by a vehicle, either present at the fuelling station or passing by on a nearby road)	m		2-5				3	5	10	8	
		m		12-35		5				25	-	
CLEARANCE DISTANCES *The clearance distance is the minimum distance between the potentially hazardous installation /equipment and the vulnerable targets within the fuelling station. Here, the hydrogen installation is regarded to be the source, while the surrounding people / objects are considered to be the targets.*	Personnel of the HRS (1st party)	m									-	
	Users of the HRS (clients, 2nd party)	m					10				-	
	Public (Third party)	m									8	4,6
	Other fuelling facilities within the fuelling station, like delivery facilities.	m								12		
	Gasoline storage	m	3,1 to 7,6 (below ground)	3-8		3	10			25	8	4,6
	LPG storage	m	7,6 to 15,2 (above ground)			8	20			25	8	4,6

Table A.1 *(continued)*

			CA	CN	FR	DE	IT	JP	KR	SE	UK	US
	CNG hazardous elements	m	7,6 to 15,2	5-12			15	6		12	5	4,6
	Bulk liquid oxygen storage	m	7,5 to 15			5		10	10 (5 if firewall)	12	5	
	Between H2 dispensing and others fuels (LPG, CNG, gasoline)	m		4			8				-	4,6
	Buildings inside the plant	m		5-15	8					12	-	
	Building of combustible material	m	15,2							12	8	4,6
	Building openings / windows / access doors	m	3,1 to 7,6							Same as for buildings in general	8	10,7
	Building non combustible material	m	1,5 (2 h) 7,6 (< 2 h)								-	1.6
	Air intakes / ventilation	m	15,2			Out of hazardous area				Outside of hazardous area	8	10,7
	Other	m	4,6 (haz. mat. piping)								-	
EXTERNAL RISK ZONE *The external risk zone is the distance (or area) outside the fuelling station which has to be protected against hazards caused by the hydrogen installation. Here, the H2 installation (i.e. dangerous units thereof) is clearly the hazard source, while people and constructions offsite are regarded to be the target(s).*	Lot line	m	1,5		8			8	10 (5 firewall)		8	10,7

Table A.1 *(continued)*

			CA	CN	FR	DE	IT	JP	KR	SE	UK	US
	Public Road	m	4,6	5-15	8			8	5	10 (up to 50 km/h)	8	3 (Dis-pen-ser)
	Specific public buildings Houses	m							12-20		-	
	Parking	m	4,6							6	8	4,6
	School / Hospital Place of public assembly / Other	m	15.2	50					17-30	100 (exits from difficult to evacuate buildings)	-	

Table A.1 *(continued)*

			CA	CN	FR	DE	IT	JP	KR	SE	UK	US
	High voltage line	m	15 tram, bus overhead 1,5 others overhead electrical	1.5 times of the height of the pole			30		5 (Rail 30)	15 (Valid for 12-72,5 kV)		4,6
Comments:									where “-” is un-specified			

NOTE: CASourced from CHIC, Canadian Hydrogen Installation Code, CAN/BNQ 1784-000/2007, Table 2, for gaseous hydrogen storage greater than 35 kg

CN: The values provided above for China have been derived from Chinese National Code GB 50516-2010: Technical code for hydrogen fuelling station.

FR: The values provided above for France have been derived from the specific French regulation “Arrêté du 12 février 1998 relatif aux prescriptions générales applicables aux installations classées pour la protection de l’environnement soumises à déclaration sous la rubrique n° 1416 (Stockage ou emploi de l’hydrogène) : for stored quantity of hydrogen between 100 kg and 1 T.

Values provided available for installations using gaseous hydrogen:

- Distance can be reduced to 5 m if located in a dedicated closed building
- Distance can be reduced to 3 m by installing a dedicated fire-resistance wall

DE: The values provided above for Germany have been derived from the VdTÜV-Merkblatt: Compressed gases 514: Requirements for hydrogen fuelling stations and other sources.

IT: The values provided above for Italy have been derived from the Italian Regulation of the 2006-08-31: Technical rule for the design, construction and exercise of hydrogen refuelling stations.

JP: The values provided above for Japan have been derived from High Pressure Gas Safety Law, Code of General High Pressure Gas Safety Article 7-3 Paragraph 2. These distances are applied for gaseous hydrogen systems (< 82 MPa) and liquid hydrogen storage (< 1 MPa).

KR: The values provided above for Korea have been derived from interpretation of the High Pressure Gas Safety Management Law and KGS FP216.

SE: Swedish distances are based on distances used for CNG-stations. They can be found in TSA 2015, “Anvisningar för tankstationer för metangasdrivna fordon”, published by The Swedish Gas Association (Energigas Sverige).

Note that most of the values are valid for storage volumes larger than 4000 litres. Shorter distances are available in TSA for smaller volumes and for dispensers. Many of the distances may be halved with walls with 1 h fire resistance.

UK: The values provided above for the UK have been derived from interpretation of the published British Compressed Gases Association (BCGA) Code of Practice CP41, 2014 - The design, construction, maintenance and operation of filling stations dispensing gaseous fuels. These distances are based on those for bulk gaseous hydrogen storage published in BCGA Code of Practice CP33. Other distances may apply for smaller gaseous hydrogen storage systems, or for liquid hydrogen storage.

US: NFPA 2: Derived from National Fire Protection Association (NFPA) Code 2, for gaseous hydrogen systems of a pressure between 51,7 MPa to 100 MPa, and with a piping system of internal diameter 7,16 mm. (also NFPA 55: Compressed gases and cryogenic fluids code)

Annex B
(informative)

Proposal for hydrogen fuelling verification of the SAE J2601 fuelling protocol

B.1 General

In order to properly verify hydrogen dispenser functional operation according to SAE J2601, new hydrogen fuelling stations should ensure the following:

— The fuelling protocol SAE J2601 has been properly implemented including fault shut-off confirmation (especially the vehicle fuelling safety parameters (including CHSS limits) are not exceeded

— The performance targets for fuelling including average pressure ramp rate and cooling capacity, etc. are met.

B.2 Factory acceptance and site acceptance testing

B.2.1 Factory acceptance testing vs. site acceptance testing

Table B.1 below gives an overview of tests which should be completed for all stations brought into service. Some of these tests can be performed as Factory Acceptance Tests (FAT), and are accepted without the need for replication when the station is installed on-site. If this is not possible, these tests should be performed as field validation testing.

Some FAT may be representative of multiple stations, for example where identical control software is used and do not need performing on each identical station. Additional details of testing is planned to be covered in the future ISO 19880-1.

Table B.1 — Dispenser function tests

Dispenser function tests	FAT	SAT
Confirmation that tables are correctly programmed into PLC through software means.	Yes	No [a]
15 Fault Simulation Testing (see Table B.2). However Abort Signal to also be tested in both FAT and SATs	Yes	No [a]
9 Site Acceptance Tests including 1-2 top off from low start pressure (see B.3.3.4). Verification that Measured Fuelling performance Parameter are within limits Gas Temperature Window, Flow Rate and Pressure targets are within bounds of Fuelling protocol	No	Yes

[a] unless not included in FAT, in which case it is carried out on site.

B.2.1.1 Factory acceptance testing - general

The FAT of dispensers is expected to be carried out before the fuelling station is commissioned in order to prove the functionality of the safety and performance systems of the fuelling station according to SAE J2601. This could take place in a simulated environment to evaluate that the dispenser applies the protocol correctly under a wide range of conditions, and that it responds properly to out-of-bounds conditions (upset conditions) which cannot be replicated in the field. This should include simulated software testing, hardware loop testing but can optionally include hydrogen fuelling with a Hydrogen station testing apparatus (HSTA).

The Factory Acceptance Tests are mainly focussed on the minimum safety tests as described in the next clause.

It is assumed that the data from the pressure and temperature signals of dispenser will be provided from the station owner/operator.

Table B.2 — Example of dispenser factory acceptance tests

Test no.	Function	CHSS IrDA	Preparation to be performed	Possible to perform also with fuelling (Site Acceptance Test)	Acceptable test
1	Fault: Ambient temperature (T_{amb})	No	Influence T_{amb} measurement to < -40 °C by manipulation of transmitter signal loop	N/A	Main fuelling part is not allowed to start
2			Influence T_{amb} measurement to > 50 °C by manipulation of transmitter signal loop		
3	Fault: CHSS starting pressure	Yes	Refuel with< 0,5 MPa starting pressure by manipulation of transmitter signal loop	N/A	Main fuelling part is not allowed to start.
4			Refuel with > 70 MPa starting pressure by manipulation of transmitter signal loop		
5	Fault: Excess hydrogen flow	No	Manipulation of transmitter signal loop to produce a signal greater than 60 g/s. Additional hardware might be required for manipulation of signal without software change.	Hydrogen mass flow measurement to be less than 60 g/s after 30 s start-up	Fuelling Stop within 5 s with out-of-bounds.
6	Fault: Dispenser only Absolute hydrogen delivery temperature	No	Manipulation of dispenser signal for upper and lower delivery temperature below -40 °C and above 85 °C. The "cool down window" to be confirmed during SAT (but can optionally be confirmed during the FAT).	After a period of > 35 s influence hydrogen delivery temperature measurement under the lowest permitted temperature (e.g. <-40 °C @ T40 Stations)	Fuelling Stop within 5 s with out-of-bounds.
7	Hydrogen delivery pressure monitoring	No	Manually calculate expected APRR based on observed starting conditions	Influence hydrogen delivery pressure measurement above APRR $_{Corridor}$	Fuelling Stop within 5 s with out-of-bounds. Compare the manual calculated APRRwiththe actual (ideal) APRR The two valuesmust be within±1 % (Tolerance value to be evaluated).
NOTE Factory Acceptance Testing of dispensers is not fully described in this publication of ISO/TR 19880-1. It is expected the supplier will conduct a comprehensive testing program to assure that the dispenser will meet the technical requirements over the expected operating conditions.					

Table B.2 *(continued)*

Test no.	Function	CHSS IrDA	Preparation to be performed	Possible to perform also with fuelling (Site Acceptance Test)	Acceptable test
8	Hydrogen delivery pressure monitoring	No	Manually calculate expected APRR based on observed starting conditions	Influence hydrogen delivery pressure measurement below APRR corridor	Fuelling Stop within 5 s with out-of-bounds. Compare the manual calculated APRR with the actual (ideal
9		Yes		Influence hydrogen delivery pressure measurement above APRR corridor: CHSS Signal	
10				Influence hydrogen delivery pressure measurement below APRR corridor. CHSS Signal	
11	Fault: Hydrogen delivery temperature monitoring	No	Disable precooling fallback	Influence hydrogen delivery temperature measurement above the allowed temperature corridor	Fuelling must be aborted (also see B.3.5)
12	Fault: Communications Abort Signal	Yes	Simulated Communications Abort Signal	See B.3.3.4	Fuelling must be aborted
13	Fault: CHSS Max temperature	Yes	Simulated CHSS IrDA Temperature signal above 85 °C	To be monitored	Fuelling Stop within 5 s with out-of-bounds.
14	Fault: Max CHSS and Dispenser Pressure	Yes	Simulated Pressure signal on both the Dispenser and the CHSS IrDA to be simulated above 125 % NWP.	To be monitored	Fuelling Stop within 5 s with out-of-bounds.
15	Fault: Maximum State of Charge		Simulated CHSS IrDA Temperature signal which creates a SOCvehicle larger than 100 %	To be monitored	Fuelling Stop within 5 s with out-of-bounds.

NOTE Factory Acceptance Testing of dispensers is not fully described in this publication of ISO/TR 19880-1. It is expected the supplier will conduct a comprehensive testing program to assure that the dispenser will meet the technical requirements over the expected operating conditions.

B.2.1.2 FAT: safety related functions

The following FAT outline originated from the Clean Energy Partnership with input from the ISO/TC 197. These FATs are designed to confirm the critical safety functions especially during fault conditions. Several tests should be done in advance of Site Acceptance Test through a factory acceptance test (FAT). In this case a report of the Factory Acceptance should be provided with data based results confirming each item. The objective is to simulate a condition above the limits prescribed in SAE J2601 through modification of HSTA and station signals, etc.

The following safety related functions are objects to the test:

— ambient temperature monitoring;

— excess hydrogen flow monitoring;

— absolute hydrogen delivery temperature monitoring;

— vehicle tank starting pressure monitoring;

— hydrogen delivery pressure monitoring;

— hydrogen delivery temperature monitoring;

— fuelling stop monitoring;

— SAE J2799 Tests and IrDA signal monitoring;

— precooling fallback (if this option is realized);

— vehicle volume determination (if this option is realized);

— top-Off APRR- and target pressure change (if this option is realized).

All functions are tested according to the below test matrix, listing all important prerequisites and accepted test results. Tests can also be carried out during commissioning. All tests have to include changes to specific process parameters measured by the station controller(input signals). The required parameters for testing the above safety related functions are:

— ambient temperature;

— hydrogen mass flow;

— hydrogen delivery pressure;

— hydrogen delivery temperature.

The process control system (PCS -through Hardware architecture or software) of the fuelling station is usually divided in two parts:

— operational: for all measurements, control loops required acc. to SAE;

— fail safe: for safety related functions.

To test the safety related functions, control loops should be manipulated in operational part of PCS only (e. g. change set point of control loop or manipulate measured values (e.g. temperature) during fuelling). This enables testing the safety related functions without changing the fail safe part of PLC.

At FAT, there should be paperwork presented confirming that the SAE J2601 tables have been programmed appropriately. In addition, there should be confirmation that the communications hardware has been tested to comply with SAE J2799, etc.

B.3 Site acceptance with a hydrogen station testing apparatus (HSTA)

B.3.1 Goals of site acceptance

The site acceptance testing of the dispenser should be carried using a HSTA, witnessed by a third party certification agency as required. The goal of the site acceptance with a HSTA is to be able to confirm that the fuelling is tested to adherence to the following rules:

— the communications system on the dispenser is able to process abort and stop fuelling commands issued by the vehicle (HSTA) during fuelling events and can properly use the range of communication signals from the vehicle (SAE J2799).

— the appropriate table is chosen for the Dispenser “T-Rating” with the respective pressure levels, communications option and CHSS fuelling categories.

— confirm that with a given ambient temperature and CHSS starting pressure the correct values of APRR and target pressure from the tables are used

— that there is proper interpolation of the ambient temperature and CHSS pressure and resulting average pressure ramp rate and targets are in the correct range.

B.3.2 SAE J2601 fuelling site acceptance test (no station modification) for 70MPa

The Site Acceptance testing should include representative tests according to the dispenser capability. For example, if there are two pressure levels, 35 MPa or 70 MPa, but one dispenser fuel delivery temperatures such as T40, There should be tests done to evaluate that the dispenser fuels according to J2601 and responds properly to out-of-bounds. Conditions (upset conditions) include those pressure ranges. In addition the performance of fuelling with and/or without communications should be evaluated. Testing should evaluate the ability of the dispenser to fuel compressed hydrogen storage system (CHSS) of the different capacity categories (2-4 kg, 4-7 kg, 7-10 kg) according to the dispenser capability. All fuelling stations should be tested at each dispenser and each nozzle connection (e.g. H35 and H70), however it is up to the station tester to determine how many repeated tests are done. Reference B.3.3.4.

It is assumed that the data or access thereof from the pressure and temperature signals of dispenser will be provided from the station owner/operator and the HSTA. The data recording rate needs to be recorded from the start of connection to end of fuelling- at a minimum at a rate of 1 Hz. The minimum station data provided should be:

— the station ambient temperature sensor reading

— dispenser hydrogen temperature and pressure sensors

There should be site acceptance Testing of the fuelling function with the HSTA. The goal is to test the fuelling functionality with no station modification in order to confirm the fuelling parameters are within scope under normal operation. There should be a minimum of eight SAE J2601 valid fuelling tests carried out for each dispenser nozzle (pressure level, T Rating). Pass Criteria to be within Table B.3 limits. However discretion is allowed for performance deviate. If possible, at least one test should be done at a different station's CHSS size category.

B.3.3 Conditions of site acceptance test

B.3.3.1 Ambient temperature testing

The dispenser should be tested to validate that fuelling rate is dependent upon ambient temperature. While it is not possible to control the ambient environment at a fuelling station, the initial fuelling conditions of the tests should be chosen as close as possible to a high and low ambient temperature portion of a given day.

B.3.3.2 Fuelling parameters to be tested

The following parameters should be verified to confirm the minimum performance requirements of the fuelling protocol such as SAE J2601 (see B.2.3 for a complete list of parameters):

— J2601 Process Limits for vehicle CHSS systems

— performance pressure targets from tables

— pressure tolerance window

— pre-cooling time window

— fuel temperature tolerance window

B.3.3.3 Communications testing

The HSTA should be used to validate that the IRDA communication system is functional and the dispenser accepts and processes the Abort and Halt fuelling commands properly and that faulty communication signals are recognised by the dispenser and correct actions are taken to assure safe fuelling in all conditions

B.3.3.4 Site acceptance testing with start criteria

The following tests are to be done for each dispenser at the station primarily in the 4 kg to-7 kg category. If possible for the HSTA, multiple CHSS volume categories are to be evaluated at the dispenser (e.g. 2 kg to-4 kg, 7 kg to-10 kg), list item 9.

1) Fault: Abort Signal Test: start a Communications Fuelling (start below 50 MPa). Instruct the HSTA to send a SAE J2799 Abort Signal and the station should stop fuelling within 5 s.

2) Top Off Test (if applicable): Communications Fuelling Test with start HSTA test at 2 MPa ± 1 MPa starting pressure

3) Empty Fuelling test: Communications Fuelling Test with start HSTA test at 8 MPa ± 2 MPa starting pressure

4) Empty Fuelling test: Non-Communications Fuelling Test with start HSTA test at 8 MPa ± 2 MPa starting pressure

5) Medium Interpolation test: Communications Fuelling Test with start HSTA test at 37,5 MPa ± 2 MPa starting pressure and confirm an interpolated start pressure.

6) Medium Interpolation test: Non-Communications Fuelling Test with start HSTA test at 37,5 MPa ± 2 MPa starting pressure and confirm an interpolated start pressure.

7) HSTA Break in Communications Test: Communications Fuelling Test with start HSTA test at 20 MPa ± 10 MPa starting pressure. HSTA is to break communications after 20 s to 30 s and fuelling is to continue with non-communications or stop.

8) Repeat of one test 2-6 (judgment of testing house) to confirm consistency.

9) Repeat test number 3 for each CHSS volume category of the dispenser / HSTA not already tested. If the dispenser was not designed to fuel other categories (2 kg to 4 kg, 7 kg to 10 kg) then the dispenser is to shut down with the simulated IrDA signal.

B.3.4 Acceptance criteria of testing (according to SAE J2601)

Table B.3 lists the acceptance criteria for the fuelling at a hydrogen station along with the reference clause in SAE J2601.

Table B.3 — Global acceptance criteria for all hydrogen fuelling testing to SAE J2601 (both SAT and FAT)

Criteria	Fuelling limits	SAE J2601 clause reference
Ambient temperature of operation Ambient temperature sensor (simulated signal)	-40 °C < Tamb < +50 °C	7.2.2
Vehicle tank starting pressure monitoring (simulated signal via IrDA receptacle) Dispenser pressure sensor (simulated signal, for instance by increasing 0,5 MPa to 5 MPa for a 2 MPa start pressure)	< 0,5 MPa < P_0< NWP	7.3.1
Maximum flow rate Dispenser flow sensor (simulated signal)	Flow Rate ≤ 60 g/s	7.42
Fuel delivery temperature Dispenser temperature sensor (simulated signal)	-40 °C < Tfuel	6.6
[a] In a fault condition, it is permissible to have up to 115 % SOC only with communications		

Table B.3 *(continued)*

Criteria	Fuelling limits	SAE J2601 clause reference
Vehicle CHSS gas temperature (simulated signal via IrDA receptacle)	-40 ºC < Tvehicle ≤ 85 ºC	6.6
Maximum mass of hydrogen allowed during start-up (not to be exceeded during the defined Site Acceptance Tests)	Total H2 mass prior to start of fuelling < 200 g (measured at HSTA, flow meter, etc)	7.4.3
CHSS Capacity* (simulated signal via IrDA receptacle – out-of-bounds. , and each applicable CHSS volume category) (simulated signal of combined dispenser pressure and flow meter, including simulated volume outside those permitted) (correct CHSS volume category to be verified during the defined Site Acceptance Tests for different volumes according to HSTA capability, such as 2 kg to 4 kg, 4 kg to 7 kg categories)	2 kg to 4 kg, 4 kg to 7 kg, 7 kg to 10 kg CHSS volume categories as applicable 85 % CHSS Cap Actual <CHSS Cap Measured < 115 % CHSS Cap Actual	9.2
Fuel delivery temperature at start-up Dispenser temperature sensor (simulated signal during simulated or HSTA fuelling event)	Tfuel category min < Tfuel within 35 s (30 s +5 s tolerance) after the start of fuelling	9.1.2
Fuel delivery temperature tolerance[a] Dispenser temperature sensor (simulated signal during simulated or HSTA fuelling event)	Tfuel category min< Tfuel <Tfuel category max (1 fallback allowed if available)	9.1.2.2
Fall back test (where option exists for communication fuelling only)	• Non-communicative and communicative fuelling after 5 s • Single fallback only to the next lowest T category table • Follow the fallback procedure • Shut down if a colder fuel delivery temperature (and faster APRR) is used including switching back to the original fuel delivery temperature category.	10.9
Upper station pressure tolerances[a] Dispenser pressure sensor (simulated signal during simulated or HSTA fuelling event)– for instance using lower limit than permissible, e.g. 0,1 MPa)	Pstation ≤ P0 + (APRRtarget) (tfuelling) + ΔPupper, where ΔPupper = 7,0 MPa	9.3.2
Lower station pressure tolerances* Dispenser pressure sensor (simulated signal during simulated or HSTA fuelling event)– for instance using higher limit than permissible, e.g. 0,1 MPa)	Pstation ≥ P0 + Max [((APRRtarget) (tfuelling) – ΔPlower), 0], where ΔPlower = 2.5 MPa	9.3.2
Cycle control (Ensure software has a counter for unintentional fuel stopping events)	Fuel flow stoppage (below 0,6 g/s) may not happen more than 10 times during a fuelling event	9.4

[a] In a fault condition, it is permissible to have up to 115 % SOC only with communications

Table B.3 *(continued)*

Criteria	Fuelling limits	SAE J2601 clause reference
Communication end of fuelling	Fuelling Stops when Pstation = Ptarget, and/or 100 % < SOCvehicle [a]	10.8.13
Non-Communication End of Fuelling	Fuelling Stops when Pstation ≤ Ptarget	10.7.2
Maximum pressure Dispenser pressure sensor (simulated signal) CHSS (simulated signal via IrDA receptacle)	Pvehicle ≤ 125 % NWP	7.33
Non communications Maximum state of charge (with HSTA) (not to be exceeded during the defined Site Acceptance Tests)	SOCvehicle ≤ 100 % (measured at HSTA)	7.4.1

[a] In a fault condition, it is permissible to have up to 115 % SOC only with communications

B.3.5 Optional fallback test

According to SAE J2601 10.9, if there is a fault where the fuel temperature goes out of the acceptable tolerances, the station dispenser will either terminate fuelling or -with communication- may use a so-called “Fallback” Procedure.

The SAE J2601 Fall Back procedure shifts the fuelling APRR to a warmer “T” category and therefore slows the fuelling rate. For example, if a station dispenser is fuelling using a T40 rated dispenser (with a temperature window of -33 °C to -40 °C, and is unable to maintain the fuel temperature limits it can shift to a slower “Fall Back Pressure Ramp Rate” using the T30 tables. This is with the same volume and ambient temperature category, etc. as the initial condition.

It is anticipated that this fallback condition to happen only in very rare cases such as over demand conditions where many more vehicles are fuelled that the station was designed for. In order to test for the fall-back condition, the station dispenser is to be tested at its “T” fuel temperature rating (e.g. T40).

The station dispenser hydrogen temperature sensor signal is to be modified so that it goes outside the T window (e.g. outside T40 window with -30 °C). This is done with and without the communications active on the HSTA device.

Test conditions:

— use ambient temperature for fuelling start;

— HSTA CHSS pressure at start-up 10 MPa (+/- 2 MPa);

— hydrogen fuel temperature–out-of-bounds signal- +3 °C above the fuel temperature tolerance (T40 = -30). in approximately 30 s after fuelling;

— minimum 2 tests: HSTA first without communications and then with communications.

Pass criteria:

— for non-communications, after the fuel temperature –out-of-bounds signal-, the station should shut down after 5 s.

— for communications after the fuel temperature –out-of-bounds signal-, within 5 s the dispenser should either shut down and/or demonstrate that the ramp rate follows FPRR formula[4] in SAE J2601. The stop condition is either an out-of-bounds of temperature and pressure according to SAE J2601 or the Pressure target from the warmer T rated table (e.g. T30). The FPRR should not go to more than one T rating and should shut down if this were to occur.

B.3.6 General

B.3.6.1 Hydrogen station testing apparatus (HSTA)

In order to test a hydrogen dispenser system, a HSTA should be made to simulate a vehicle CHSS so that test fills from the dispenser can be made and fuelling performance measured and evaluated.

The HSTA should have and IRDA communication interface to the dispenser and an ability to test the functioning of the communication system on the dispenser. For example, the HSTA should be able to be programmed to send abort and halt fuelling commands to evaluate the dispenser response. The communication system may also be designed to send faulty temperature or pressure signals to determine if the dispenser will adapt and perform safe fill in the event of faults in the communication signal from the vehicle (HSTA)

The HSTA may be a simple device that use only one size tank system or may be fitted with multiple tanks to be able to test all applicable CHSS fuelling categories (2-4 kg, 4-7 kg, 7-10 kg).

In B.3.6.2 there is an example of key technical points for a general hydrogen station test apparatus. A specification is including with a basic P&ID diagram to give guidance for a fuelling verification device. It is recommended that a safety evaluation (Risk Assessment, FMEA, etc.) is done on the HSTA.

B.3.6.2 HSTA hydrogen storage specification

— hydrogen storage systems that have at a minimum rated capacity of between 4-7 kg hydrogen at 70 MPa and 15 °C,

— optional additional Storage systems to enable testing of the other pressure classes of 7-10 kg and 2-4 kg.

— all storage systems in the HSTA should utilize an appropriately rated hydrogen storage vessel(s) that conform to CSA-HGV-2 or equivalent, or vehicle fuel systems that conform to SAE J2579 and/ or the Global Technical Regulation 13 for hydrogen vehicle fuel systems

— the HSTA should have a pressure drop between the receptacle and fuel table of less than 20 MPa according to requirements within SAE J2601. Ideally, the pressure drop should be within 17-19 MPa.

B.3.6.3 HSTA system components

— appropriate H-Rate receptacle (see ISO 17268)

— SAE J2799 IrDA system (for communication fuelling and evaluation of dispenser IRDA function and IRDA signal error processing.)

— spring activated pressure relief valve(s) (optional)

— thermally activated pressure relief device(s)

— gas leak detector

— means of venting with flow restriction

— manual and automatic isolation valves

— filter

B.3.6.4 HSTA fuelling data collection

— data recording

— inlet hydrogen gas temperature and pressure downstream of receptacle

— tank gas temperature and pressure (vehicle representative position)

B.3.6.5 Example HSTA layout (P&ID) from ENAA

Figure B.1 shows an example of a HSTA P&ID (provided by ENAA and HySUT) with sensors and valve layout from an HSTA used in the field. This particular example shows one fuelling vessel. The component layout and inventory should be investigated according to local requirements and the accompanying risk assessment.

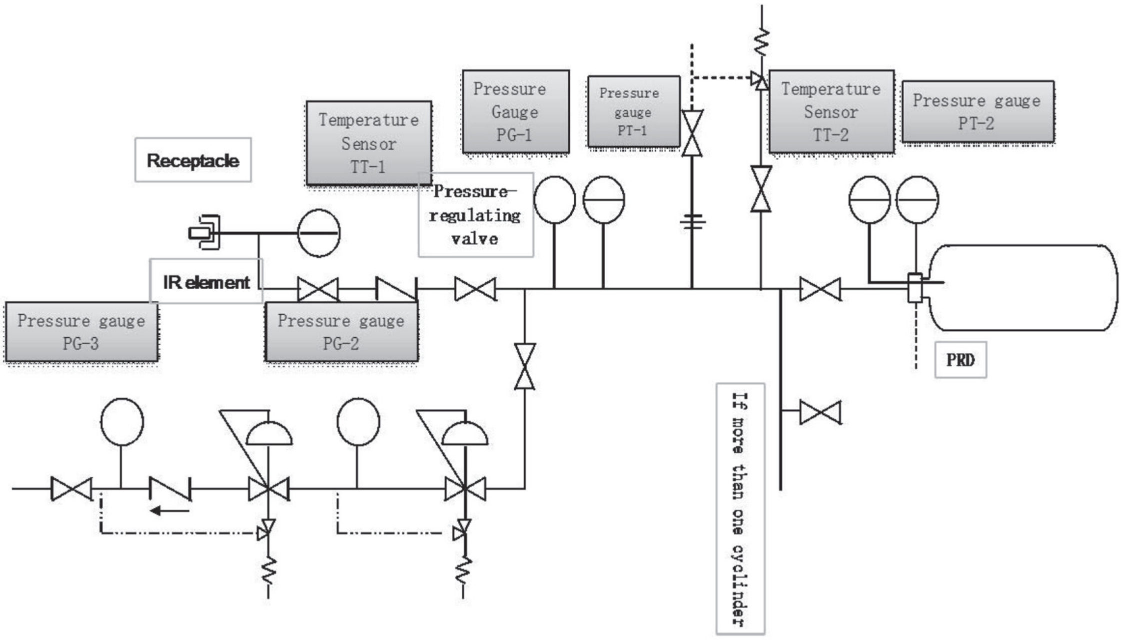

Figure B.1 — Example of a HSTA P&ID

B.3.6.6 Example HSTA layout (P&ID) from the US DOE and Sandia National Labs

Figure B.2 shows an example of a Hydrogen Station Test Apparatus P&ID called the HyStEP Device (provided by the US Department of Energy and Sandia National Labs under the H2FIRST project) with sensors and valve layout from an HSTA used in the field. This particular example shows three fuelling vessels that can be individually controlled to simulate CHSS fuelling from 3 kg, 6 kg or 9 kg. The component layout and inventory should be investigated according to local requirements and the accompanying risk assessment.

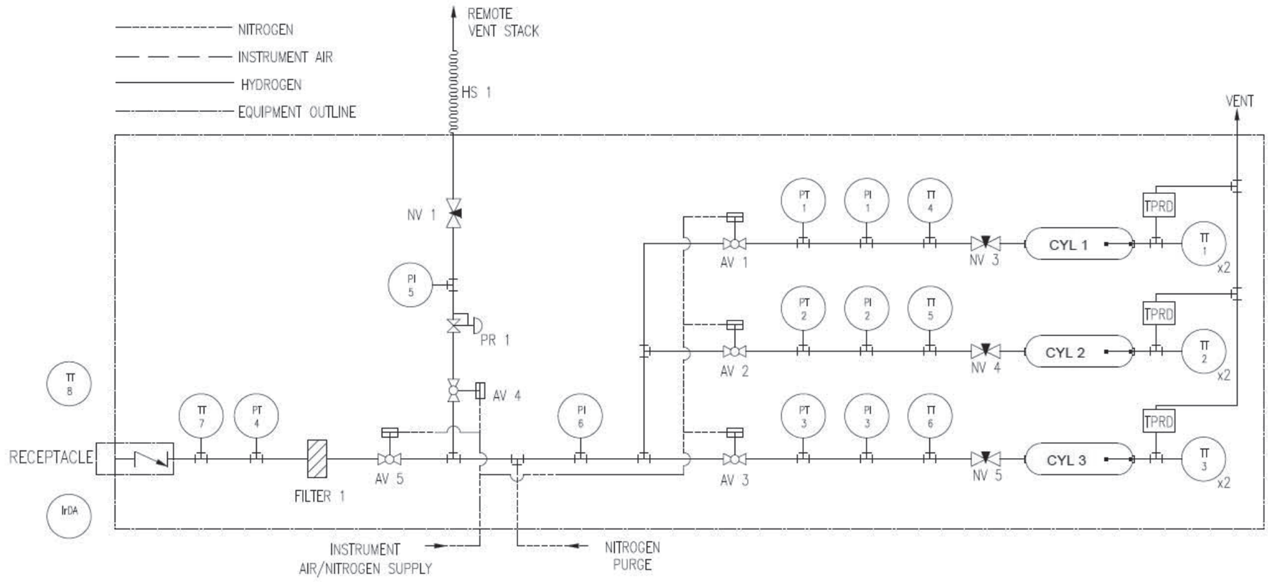

Figure B.2 — Example of a HSTA P&ID called the HyStEP device

Annex C
(informative)

Example matrices for guidance for hydrogen quality control

C.1 General

As an example, Table C.1, C.2 and C.3 show the impurities which could be a concern for hydrogen quality dispensed to fuel cell vehicles depending on the source of hydrogen, the process equipment used in the station, and fuelling station maintenance and commissioning activities.

The station operators should consider which of these impurities they should monitor continuously or on a periodic basis depending on the source of hydrogen and following a risk assessment for the hydrogen quality.

The components of the fuelling station should not add contamination to the hydrogen fuel.

Table C.1 below shows the impurities of concern dependent upon the source of hydrogen to the fuelling station.

Table C.2 shows the impurities of concern dependent upon the purification and compression technologies utilized in the fuelling station.

Table C.3 shows the impurities of concern dependent upon the potential for atmospheric contaminants, and impurities introduced during the construction of the fuelling station and maintenance procedures

C.2 Continuous monitoring of impurities of concern

When hydrogen production or purification systems are located on-site at the fuelling station, the process, or impurities that could result from production process upset conditions should be monitored continuously, or as routinely as necessary according to the risk assessment of the process.

For example, impurities of concern for on-site hydrogen production systems may be H_2O in the case of electrolysis and CO in the case of hydrogen production from CxHy sources. See Table C.1 and refer to the risk assessment of the fuelling station to determine the needs and best location for impurity analysis.

The fuelling station compression and other processing sub-systems should not contribute impurities to the hydrogen fuel. Refer to the fuelling station risk assessment and Table C.2 for the list of impurities of concern that may be introduced into the fuel dispensed under process upset conditions.

The fuelling station risk assessment should consider the recommendations in Table C.1 and Table C.2 and implement a continuous monitoring system of the process, or for impurities that may be present due to process upset conditions on the hydrogen supply and processing systems.

C.3 Fuelling station technology validation

Table C.2 also includes sulphur, particles and total halogenated compounds and these impurities should be tested for at the nozzle when the fuelling station is commissioned and according to the risk assessment requires after fuelling station sub-system maintenance and service activities that may affect hydrogen quality at the dispenser nozzle.

Table C.1 — Example testing guideline: hydrogen quality data vs. hydrogen fuel source matrix

Impurity Constituents	Source of compressed hydrogen fuel								
	Delivered H2		Electrolysis		SMR			By-product	
	GH_2 without certificate	LH_2	Alkaline	PEM	Natural Gas	Bio Gas	CH_3OH	Chloro process	CxHy
Water (H_2O)	X		X	X	X	X	X	X	X
Total hydrocarbons	X								
Oxygen (O_2)	X		X	X				X	
Helium (He)	X								
Nitrogen (N_2) and argon (Ar)	X							X	X
Carbon dioxide (CO_2)	X				X	X	X	X	X
Carbon monoxide (CO)	X				X	X	X		X
Total sulfur compounds	X					X			
Formaldehyde (HCHO)	X					X	X		
Formic acid (HCOOH)	X					X	X		
Ammonia (NH_3)	X					X		X	X
Total halogenated compounds	X		X					X	
Particulates	X								
Additional information	Depending on certificate								

Table C.2 — Example testing guideline: impurities of concern associated with on-site hydrogen purification, fuel compression and processing

Impurity Constituents	Process equipment						
	Compressor			Cryo-pump	Hydrogen purification		
	Diaphragm	Ionic	Piston		Desiccant dryer	PSA	Pd membrane
Water (H_2O)					X[a]		
Total hydrocarbons	X	X	X				
Oxygen (O_2)							
Helium (He)							
Nitrogen (N_2) and argon (Ar)							
Carbon dioxide (CO_2)							
Carbon monoxide (CO)						X[a]	X[a]
Total sulfur compounds	X	X	X				
Formaldehyde (HCHO)							
Formic acid (HCOOH)							
Ammonia (NH_3)							

[a] Only if present in the source of hydrogen supplying the purification method

Table C.2 *(continued)*

Impurity Constituents	Process equipment						
	Compressor			Cryo-pump	Hydrogen purification		
	Diaphragm	Ionic	Piston		Desiccant dryer	PSA	Pd membrane
Total halogenated compounds							
Particulates	X	X	X	X	X	X	X
Additional information							
[a] Only if present in the source of hydrogen supplying the purification method							

C.4 Protection of the components of the fuelling station during construction and maintenance procedures

During construction and major maintenance of the fuelling station, care should be taken to keep all environmental contaminates such as water, oil, metal fragments, dust, and dirt from contaminating the fuelling station subcomponents and connective piping systems during construction and service procedures.

When fluids are used for pressure testing of field manufactured piping sections, care should be taken to remove all fluids and protect prefabricated fuelling station subsystems from contamination and systems should be purged with high quality hydrogen.

C.5 Validation of hydrogen quality at commissioning and after significant maintenance procedures

After maintenance or installation of fuelling station piping and components, any cleaning agents and purging gases should be removed and hydrogen quality should be tested before restarting dispenser operations.

Table C.3 shows the impurities of concern associated with fuelling station construction, commissioning and maintenance.

Table C.3 — Example testing guideline: impurities of concern associated with fuelling station construction and maintenance

Impurity constituents	Reason for concern
Water (H_2O)	Water from ambient source, testing fluids and low quality hydrogen
Total hydrocarbons	Oil with may be introduced during system construction or maintenance, adsorption (into H2) from incompatible polymers
Oxygen (O_2)	Ambient contamination
Helium (He)	If helium is used for pressure testing or purging
Nitrogen (N_2) and argon (Ar)	Nitrogen when used for purging or ambient contamination
Carbon dioxide (CO_2)	
Carbon monoxide (CO)	
Total sulfur compounds	Oil with sulfur may be introduced during system construction or maintenance, adsorption (into H2) from incompatible polymers
Formaldehyde (HCHO)	
Formic acid (HCOOH)	

Table C.3 *(continued)*

Impurity constituents	Reason for concern
Ammonia (NH_3)	Ammonia may be present in Cleaning Fluids, adsorption from incompatible polymers into H2 fuel
Total halogenated compounds	Halogenated compounds should not be used for cleaning fluids
Particulates	Particle testing should be done to confirm all filters are working correctly

C.6 Example of the common practice of the quality control

C.6.1 Purpose

This part of the informative annex is intended to provide an example of how quality assurance for hydrogen production processes and supply to FCEVs has been recommended in Japan, see C.6.2 to C.6.6 (a translated summary is provided here due to the document not being available in English). The example practice, including an example of a Hydrogen Quality Control Sheet (Table C.4), is intended to provide a guideline that hydrogen production facility, delivery and fuelling station operators in Japan can implement in their routine work basis to demonstrate that hydrogen fuel meets the specifications listed in ISO 14687-2. This reflects the experience and learning from hydrogen production and supply to FCEVs in demonstration activities in Japan. Process simulation and other analyses also provide theoretical and technical support for this recommended practice.

Part of the aim of carrying out hydrogen quality risk assessment for each station, and the whole hydrogen supply chain, should be to define which analyses would be relevant to the station to be able to justify the control of hydrogen quality. It is acknowledged that some of the control measures recommended in Japan would not be applicable to all scenarios, and the regular testing of more, or less, contaminants could be appropriate according to the specific station risk assessment.

Where CO is considered to be a likely contaminant, as indicated in Table C.4, it should be monitored on a routine basis, however the rest of the constituent sampling frequency is to be determined in the future ISO 19880-1.

Without any dedicated hydrogen quality risk assessment or quality control system, the constituents identified in Table C.4 depending on the type of hydrogen supply should be analysed daily. With an appropriate risk assessment and quality control system, the frequency of testing can be reduced to a maximum interval of once per year.

C.6.2 Basic principle for practice of quality assurance

It is important at station commissioning to do an entire suite of testing. At the same time it is critical for many reasons to give guidance to testing and monitoring key impurities that are likely to be in the hydrogen supply chain from the feed stock all the way to the dispenser nozzle.

Hydrogen quality control gives an opportunity to reduce testing and frequency requirements (while keeping the same quality level as ISO 14687-2) for those specified impurities unlikely to be in the dispensed hydrogen.

The analysis practices are classified into the following two categories; routine analysis and non-routine analysis. Beside of these two categories of analysis, all of the constituents listed in the Table 1 of ISO 14687-2 should be analysed at least once every year or every appropriate period, for the identification of the quality of the hydrogen fuelled at the nozzle of the station.

C.6.3 Frequency of routine analysis

C.6.3.1 Routine analysis at a centralised production and distribution facility

As a general rule, the product quality of a plant is consistent regardless of the size of its production system, as long as the feedstock and the operating conditions are consistent. If there are no changes in the feedstock and the operating conditions over a long period of time, only one quality analysis is needed per operation period. The principle of quality control is to perform a daily analysis. Types of analysis, in order to ease the analytical burden of hydrogen stations and, at the same time, maintain full quality control. However, when the feedstock and the operating conditions have not changed and if it can be assured that the possibility of contamination is eliminated by the good operation and control of the distribution facility by, for example, continuously monitoring the canary species before shipping, the test frequency may be reduced to as low as once per year.

Where the hydrogen generators (such as reformers, water electrolysis apparatus or other processes) on the supply side of a distribution facility are operated intermittently and if it can be assured that the possibility of contamination is eliminated by the good operation and control of the distribution facility by, for example, continuously monitoring the canary species following the start of the hydrogen generators, the frequency of analysis may be reduced to as low as once per year.

In this document, the good operation and control means not only that the facility has a continuous analytical instrument installed but also that such analytical equipment is calibrated and otherwise properly maintained to produce appropriate results at all times.

While sampling is to be, as a rule, conducted on the distribution side (transfer side), a separate sampling line may be used as long as it does not raise any quality control issues.

C.6.4 Routine analysis at a hydrogen station

C.6.4.1 Hydrogen stations with off-site supply

Hydrogen received by an off-site hydrogen station is subject to a routine analysis for the constituents that have not been covered by the centralized hydrogen production and distribution facility and for those that may contaminate the gas after it is accepted by the station. For individual contaminant species that may enter after station acceptance, the frequency of analysis may be reduced to as low as once per year, provided that the possibility of contamination is deemed eliminated by having a good operation and control program at the station, such as a purge procedure.

While sampling is to be, as a rule, made at the end of a nozzle, it may be conducted upstream of the fuelling nozzle to the extent that no changes occur to the quality of hydrogen.

C.6.4.2 Hydrogen stations with on-site supply

When a hydrogen generator (such as reformer, water electrolysis apparatus or other processes) is operated in the daily start and shut mode (DSS), the quality of the hydrogen gas produced fluctuates on a daily basis according to the principle described in C.6.3.1. Such operation therefore calls for one analysis per day. As in the case of the centralized production and distribution facilities in C.6.3.1, the frequency of analysis may be reduced to as low as once per year, provided that the possibility of contamination is deemed eliminated by the good operation and control of the station, such as when accumulators are filled after the canary species is continuously monitored for quality control on a daily basis following the start-up the generator. In this document, the good operation and control means not only that the facility has a continuous analytical instrument installed but also that such analytical equipment is calibrated and otherwise properly maintained to produce appropriate results at all times.

The analysis and monitoring of specific canary species for each hydrogen generator is to be conducted in the same manner as described in C.6.3.1.

While sampling is to be, as a rule, made at the end of a nozzle, it may be conducted upstream of the fuelling nozzle to the extent that no changes occur to the quality of hydrogen.

C.6.5 Conditions for conducting non-routine analysis

Irrespective of whether conditions exist for conducting routine analysis described in the preceding clause, a non-routine analysis is to be conducted for those constituents deemed necessary if:

— a new production system is constructed at a production site or hydrogen station;

— the production system at a production site or hydrogen station is modified;

— a routine or non-routine open inspection, repair, catalyst exchange, or the like is performed on a production system at the production site or hydrogen station;

— a question concerning quality is raised when, for example, there is a problem with a vehicle because of hydrogen supplied at the production site or hydrogen station, and a claim is received from a user directly or indirectly;

— an issue concerning quality emerges when, for example, a voluntary audit raises the possibility that quality control is not administered properly; or

— analysis is deemed necessary for testing, research or any other purposes.

C.6.6 Other concerns

C.6.6.1 Particulates filter

Hydrogen ISO 14687-2 specifies the maximum concentration of particulates per unit weight (1 mg/kg). Based on the causes of particulates and circumstances in which particulates occur as indicated by past analyses, the Guidelines recommend that a filter be installed in lieu of performing a routine analysis of particulates concentration.

C.6.7 Example of routine analysis and frequency of hydrogen sampling from the Japanese guideline

The principle of quality control is to perform on a routine basis analysis shown in Table C.4 according to the Japanese Guideline.

When the feedstock and the operating conditions have not changed and if it can be assured that the possibility of contamination is reduced to an acceptable level by the good operation and control of the distribution facility by, for example, continuously monitoring the canary species before shipping, the test frequency may be reduced to as low as once per year.

Beside of those practice of analysis aforementioned, all of the constituents listed in the Table 1 of ISO 14687-2 should be analysed at least once every year or every appropriate period.

Table C.4 — Principle of hydrogen quality control taken as an example from the Japanese Guideline (Routine Analysis)

Category	Facility type	QC point	Parameter	Standard value	Reduced frequency
Distribution	1. Production of hydrogen from hydrocarbons utilizing steam reforming, catalytic reforming, partial oxidation, or ATR, purification using refining equipment, and distribution	Downstream of the purifier	TS[a]	0,004 µmol/mol	Once a year[b]
			THC as C1	2 µmol/mol	Once a year[b]
			CO	0,2 µmol/mol	Once a year[b]
			N_2+Ar	100 µmol/mol	Once a year[b]
			H_2O	5 µmol/mol (dew point ≦-66 °C)	Once a year[b]
			O_2	5 µmol/mol	Once a year[b]
	2. Electrolysis of NaCl for hydrogen; purification; and distribution	Downstream of the refiner	Halogen	0,05 µmol/mol	Once a year[b]
			N_2+Ar	100 µmol/mol	Once a year[b]
			H_2O	5 µmol/mol (dew point≦-66 °C)	Once a year[b]
			O_2	5 µmol/mol	Once a year[b]
	3. Purification of coke-oven gas; distribution	Downstream of the refiner	TS	0,004 µmol/mol	Once a year[b]
			THC as C_1	2 µmol/mol	Once a year[b]
			CO	0,2 µmol/mol	Once a year[b]
			Halogen	0,05 µmol/mol	Once a year[b]
			N_2+Ar	100 µmol/mol	Once a year[b]
			H_2O	5 µmol/mol (dew point ≦-66 °C)	Once a year[b]
			O_2	5 µmol/mol	Once a year[b]
			NH3	0,1 µmol/mol	Once a year[b]
			HCHO	0,01 µmol/mol	Once a year[b]
			HCOOH	0,2 µmol/mol	Once a year[b]
	4. Purification of by product hydrogen from ethylene plants; distribution	Downstream of the refiner	TS	0,004 µmol/mol	Once a year[b]
			THC as C_1	2 µmol/mol	Once a year[b]
			CO	0,2 µmol/mol	Once a year[b]
			N_2+Ar	100 µmol/mol	Once a year[b]
			H_2O	5 µmol/mol (dew point ≦-66 °C)	Once a year[b]
			O_2	5 µmol/mol	Once a year[b]

a Since sulfur in steam reforming is mostly found as hydrogen sulfide (H_2S), H_2S analysis may be performed in lieu of total sulfur analysis

b If the risk of contamination has been reduced by a continuous analysis of the canary species (indicator of the presence of other chemical constituents) and a proper operation control mechanism.

c If the risk of contamination has been eliminated by, for example, the use of containers dedicated to FCV hydrogen.

d Once a year analysis is required, if the risk of contamination has been reduced by a continuous analysis of the canary species and a proper operation control mechanism.

Table C.4 *(continued)*

Category	Facility type	QC point	Parameter	Standard value	Reduced frequency
Station	1.With off-site supply of transported compressed or liquid hydrogen	End of nozzle	Those not analysed by the distributor		Once a year[b]
			N_2+Ar	100 μmol/mol	Once a year[b]
			H_2O	5 μmol/mol (dew point ≦-66 °C)	Once a year[b]
			O_2	5 μmol/mol	Once a year[b]
	2. With off-site supply from hydrogen pipelines	Downstream from odorant	(Those listed for the odorant)		Once a year[b]
		End of nozzle	Those not analysed by the distributor		Once a year[b]
			CO	0,2 μmol/mol	Once a year[b]
			N_2+Ar	100 μmol/mol	Once a year[b]
			H_2O	5 μmol/mol (dew point ≦ -66 °C)	Once a year[b]
			O_2	5 μmol/mol	Once a year[b]
	3. With on-site supply of hydrogen produced from hydrocarbons utilizing steam reforming, catalytic reforming, partial oxidation, or ATR, and purification using refining equipment	Downstream of the refiner	CO	0,2 μmol/mol	Continuous and once/year[b][d]
		End of nozzle	TS	0,004 μmol/mol	Once a year[b]
			THC as C_1	2 μmol/mol	Once a year[b]
			CO	0,2 μmol/mol	Once a year[b]
			N_2+Ar	100 μmol/mol	Once a year[b]
			H_2O	5 μmol/mol (dew point ≦-66 °C)	Once a year[b]
			O_2	5 μmol/mol	Once a year[b]
	4. With on-site supply from hydroelectrolysis, and purification using refining equipment	Downstream from the refiner	O_2	5 μmol/mol	Continuous and once/year[b]
			H_2O	5 μmol/mol (dew point ≦ -66 °C)	Continuous and once/year[b]
		The end of nozzle	Halogen	0,05 μmol/mol	Once a year[b]
			N_2+Ar	100 μmol/mol	Once a year[b]
			H_2O	5 μmol/mol (dew point ≦ -66 °C at atmospheric pressure)	Once a year[b]
			O_2	5 μmol/mol	Once a year[b]

a Since sulfur in steam reforming is mostly found as hydrogen sulfide (H_2S), H_2S analysis may be performed in lieu of total sulfur analysis

b If the risk of contamination has been reduced by a continuous analysis of the canary species (indicator of the presence of other chemical constituents) and a proper operation control mechanism.

c If the risk of contamination has been eliminated by, for example, the use of containers dedicated to FCV hydrogen.

d Once a year analysis is required, if the risk of contamination has been reduced by a continuous analysis of the canary species and a proper operation control mechanism.

Annex D
(informative)

Pressure level definitions for the compressed hydrogen storage system and fuelling station dispensers

Nomenclature	Definition	Example of what is desirable for filling a 70 MPa vehicle CHSS
Sourced from SAE J2601		
Nominal Working Pressure (NWP)	The NWP is the gauge pressure that characterizes typical operation of a vehicle pressure vessel, container, or system. For compressed hydrogen gas containers, NWP is the vehicle vessel pressure, as specified by the manufacturer, at a uniform gas temperature of 15 °C and 100% SOC Equivalent to Working Pressure (WP) as defined in ISO 10286	70 MPa
Maximum Operating Pressure (MOP)	The MOP is the highest gauge pressure of a component or system that is expected during normal operation including starts, stops, and transients (e.g. 1,25 x NWP). This also coincides with the NWP CHSS pressure at 85 °C. Equivalent to Developed Pressure (DP) as defined in ISO 10286 Equivalent to Maximum Working pressure in ISO 17268	87,5 MPa
Dispenser/ CHSS Maximum Allowable Working Pressure (MAWP)	The MAWP is the maximum gauge pressure of the working fluid (gas or liquid) to which a piece of process equipment or system is rated with consideration for initiating fault management above normal operation (e.g. the vehicle CHSS MAWP = 1,1 x 1,25 = 1,38 x NWP).	96,6 MPa
First level Pressure control	1st Level (normal control process): terminate fuelling when target pressure (for example from SAE J2601 tables) is reached. This is software controlled.	Variable.
Second Level Pressure control	2nd Level (principal fault management: redundant electronic protection level): terminate fuelling when 125 % NWP (87,5 MPa for a 70 MPa dispenser; 43,8 MPa for a 35 MPa dispenser) is reached. This may be software controlled.	87,5 MPa
Third level Pressure control	3rd Level (secondary fault management is equal to MAWP. This is a fully mechanical protection level): when fuelling station dispenser PSV set point is reached. The station dispenser PSV set point should be no greater than MAWP, 1,25*NWP +10% = 1,375*NWP (96,25 MPa for a 70 MPa dispenser and 48,13 MPa for a 35-MPa dispenser).	96,6 MPa
Sourced from ISO/ 10286		
Examples of Test Pressure (TP)	Required pressure applied during a pressure test NOTE The pressure test is performed at time of manufacture (initial inspection and test) and can be performed during periodic inspection and test.	Variable

Annex E
(informative)

Examples of vehicular impact protection measures

E.1 General recommendations

Recommendations for the protection of above ground fuel systems equipment.

Site layouts should be completed such that the need for physical impact barriers is eliminated or minimized. Above ground components located near high speed roads with low angle of impact or with low speed roads with high angle of impact require installation of road restraint systems that conforms to EN 1317. These are engineered guard rail or crash cushion type systems designed to absorb much of the energy from the impact, reducing the amount of vehicle damage that would occur otherwise.

Rigid barriers are required and solutions are provided where high speed and high vehicle impact is anticipated or there is not sufficient spacing for a guard rail type of system that requires adequate spacing for deflection of rail during impact.

For low speed impact potential from on-site traffic a range of bollard type solutions are available. There are two types of solutions application dependant potential impact speed and vehicle size. A Type I bollard (150 mm diameter) to protect equipment from impact by a standard size vehicle and a Type II bollard (200 mm diameter) to protect equipment from impact by a larger vehicle.

Alternative solutions may be employed which are not noted in this standard. The rating of the impact protection should be validated that the system is engineered to meet the applicable impact forces provided in this document.

The Designer responsible for site layout and the selection of the impact protection should take into account other considerations not addressed by this standard to reduce risk of impact of equipment to as low as reasonably practicable.

Traffic calming measures such as speed bumps and high containment kerbing and similar should be considered where necessary.

E.2 Dispenser specific recommendations

Dispensers should be located on a concrete island or plinth at least 120 mm above grade, (and for example suspended from a structure where the dispenser is at least 4,25 m above the fuelling pad,) or protected using other appropriate means. If the dispensers are located on a concrete island or plinth, the distance from the edge of the raised island to each side of the dispenser should be 200 mm minimum.

An example of measures that can be used for preventing a vehicle from accidentally colliding into a dispenser in a hydrogen fuelling station, based on requirements in Japan (a translated summary is provided by ENAA Engineering Advancement Association (ENAA) here due to the document not being available in English):

a) A protective fence installed on the side of the dispenser on which a vehicle parks for fuelling:

   1) The protective fence should be at least 800 mm in height, made of piping of at least 60 mm in diameter, and buried at least 300 mm underground. Its width should be greater than the width of the dispenser.

2) The protective fence should be strong enough to withstand an impact caused by a passenger vehicle (2t) travelling at 20 km/h;

b) Installation of the dispenser on a raised island with a minimum height of 150 mm, and with a distance of at least 800 mm from the dispenser to the side of the platform that is not protected by the protective fence;

c) A fuelling nozzle suspended from a structure where the dispenser is at least 4,25 m above the fuelling pad;

d) A collision sensor (if a seismoscope is to be used instead, one that is capable of detecting vehicle collision) installed at each dispenser to detect vehicle collision. Measures should be taken to sound an alarm and automatically shut down the gas production equipment when the sensor detects collision.

The example measures 1) and 2) above are demonstrated in example in Figure E.1 below.

The structural foundation of the dispenser and the fuelling area should be adequate to support all components including vehicles to be fuelled.

Dispensers should be secured against unauthorized use outside normal operating hours. The hydrogen supply to the dispenser should be isolated at the source and dispenser according to 9.10.3.3.

Dispensers should not be located beneath a canopy nor within 1 m of the vertical projection of the canopy, except where the canopy is not capable of accumulating gas in pockets or between the canopy ceiling and roof.

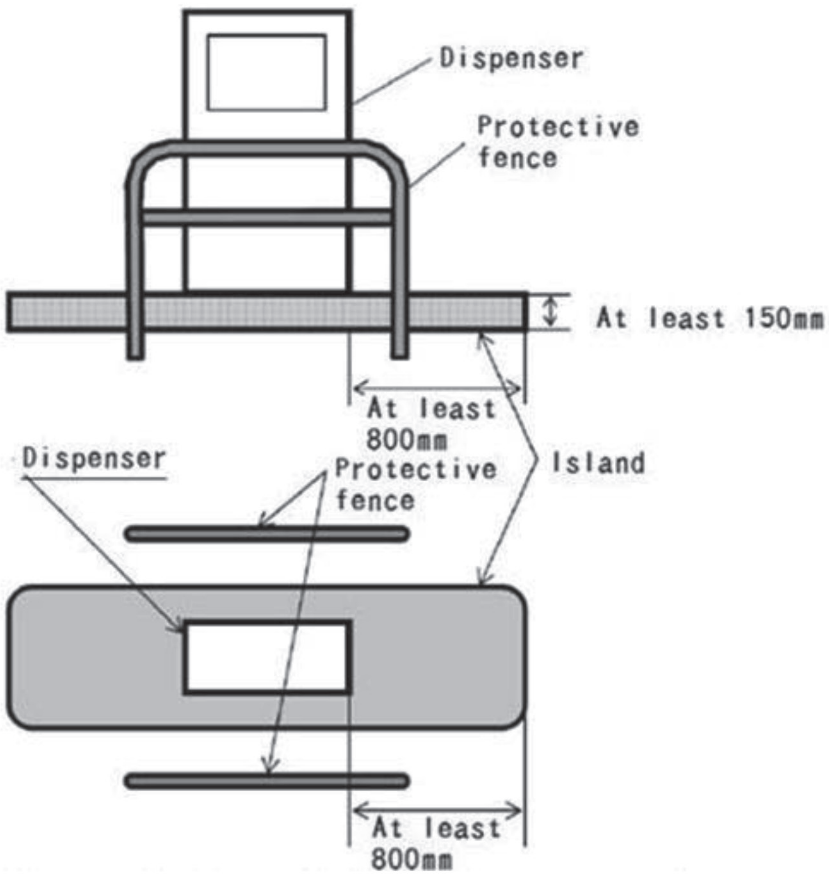

Figure E.1 — Example of a vehicle collision prevention measure as used in Japan

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