



BSI Standards Publication

Gaseous hydrogen — Fuelling stations

Part 1: General requirements

National foreword

This British Standard is the UK implementation of ISO 19880-1:2020. It supersedes PD ISO/TS 19880-1:2016, which is withdrawn.

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Gaseous hydrogen — Fuelling stations —

Part 1: General requirements

*Carburant d'hydrogène gazeux — Stations-service —
Partie 1: Exigences générales*





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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

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

This first edition cancels and replaces ISO/TS 19880-1:2016, which has been technically revised.

The main changes compared to the ISO/TS 19880-1:2016 are as follows:

- where appropriate, guidance information from the TS was converted to requirements;
- the difference between the risk assessment and the design requirement clauses were clarified and references were added to ensure that the appropriate clauses were linked;
- Annex A from the TS on safety distances was removed;
- Annex C from the TS on hydrogen quality control was removed to ISO 19880-8;
- the presentation of the information was improved and much of the guidance information was moved to informative annexes.

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

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Gaseous hydrogen — Fuelling stations —

Part 1: General requirements

1 Scope

This document defines the minimum design, installation, commissioning, operation, inspection and maintenance requirements, for the safety, and, where appropriate, for the performance of public and non-public fuelling stations that dispense gaseous hydrogen to light duty road vehicles (e.g. fuel cell electric vehicles).

This document is not applicable to the dispensing of cryogenic hydrogen, or hydrogen to metal hydride applications.

Since this document is intended to provide minimum requirements for fuelling stations, manufacturers can take additional safety precautions as determined by a risk management methodology to address potential safety risks of specific designs and applications.

While this document is targeted for the fuelling of light duty hydrogen road vehicles, requirements and guidance for fuelling medium and heavy duty road vehicles (e.g. buses, trucks) are also covered.

Many of the generic requirements within this document are applicable to fuelling stations for other hydrogen applications, including but not limited to the following:

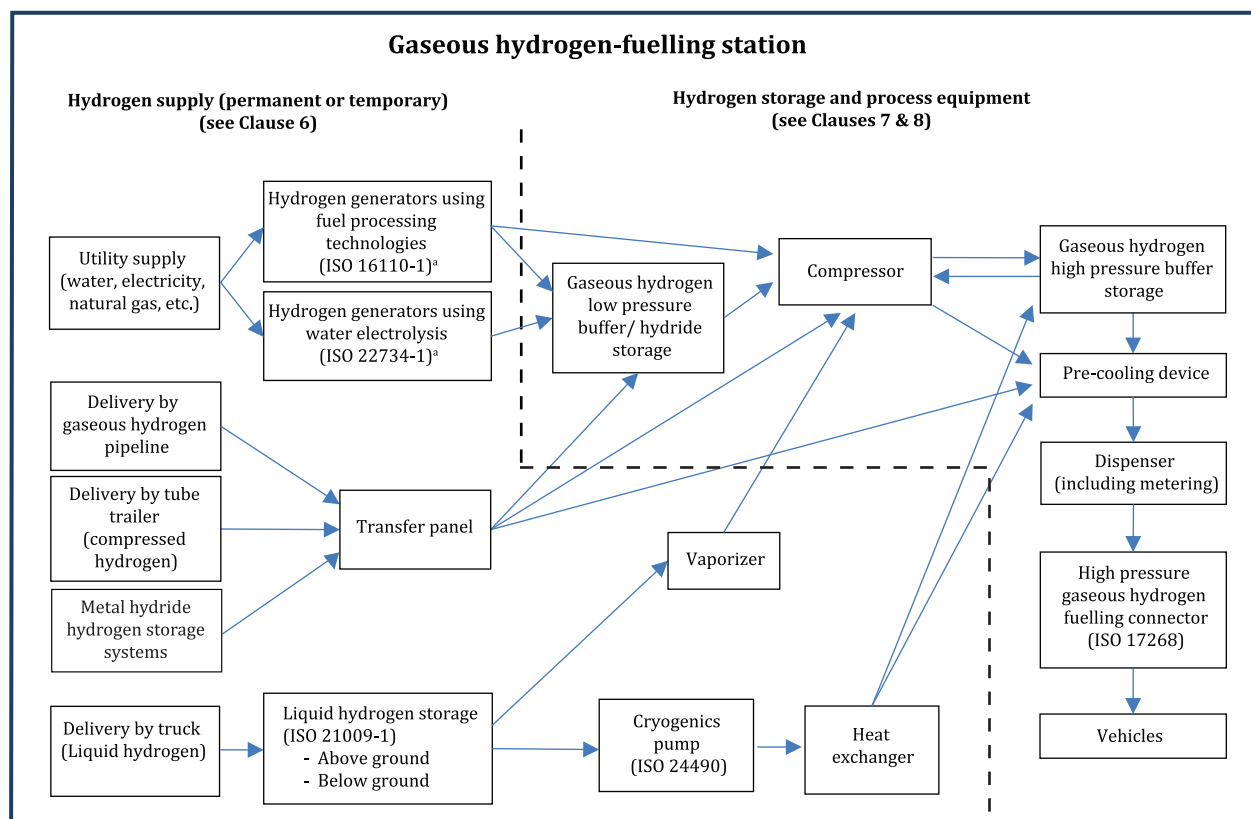
- fuelling stations for motorcycles, fork-lift trucks, trams, trains, fluvial and marine applications;
- fuelling stations with indoor dispensing;
- residential applications to fuel land vehicles;
- mobile fuelling stations; and
- non-public demonstration fuelling stations.

However, further specific requirements that can be necessary for the safe operation of such fuelling stations are not addressed in this document.

This document provides requirements for and 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 dispensing systems.



^a May include a buffer vessel (or accumulator) for dampening or adjusting flow of compressor suction inlet.

Figure 1 — Example of typical elements that a fuelling station consists of, including hydrogen supply

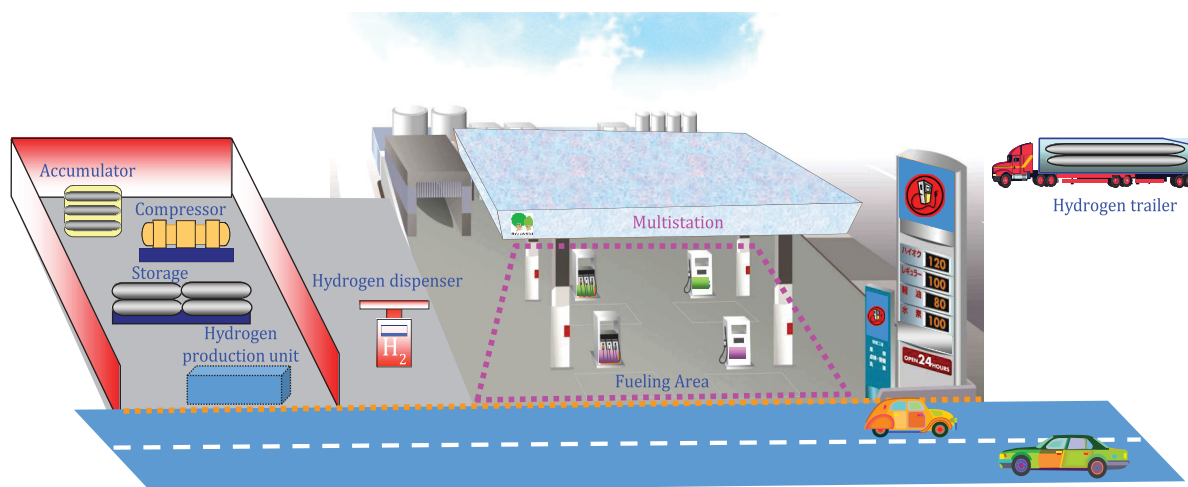


Figure 2 — Image of an example hydrogen fuelling station

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies

ISO 13850, *Safety of machinery — Emergency stop function — Principles for design*

ISO 14687, *Hydrogen fuel — Product specification*

ISO 15649, *Petroleum and natural gas industries — Piping*

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

ISO 19880-8, *Gaseous hydrogen — Fuelling stations — Part 8: Hydrogen quality control*

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

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

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

ISO 22734, *Hydrogen generators using water electrolysis*

ISO/IEC 80079 (all parts), *Explosive atmospheres*

IEC 60079 (all parts), *Explosive atmospheres*

IEC 60204-1:2005, *Safety of machinery — Electrical equipment of machines — Part 1: General requirements*

IEC 60529, *Degrees of protection provided by enclosures (IP Code)*

IEC 62282-3-100, *Fuel cell technologies. Stationary fuel cell power systems. Safety*

EN 13445-5, *Unfired pressure vessels. Inspection and testing*

SAE J2600: 2015-08, *Compressed Hydrogen Surface Vehicle Fuelling Connection Devices*

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:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <http://www.electropedia.org/>

3.1

acceptance criteria

<risk or harm > acceptable level of risk or *harm* (3.34), locally defined as:

- a tolerable risk value; or
- a specified harm level; or
- requirements in a prescriptive document

3.2

accessory

device with an operational function

3.3

bleed

<venting> intentional expiration of a fluid from a fluid system

3.4

basic process control system

BPCS

system which responds to input signals from the process, its associated equipment, other programmable systems and/or an operator and generates output signals causing the process and its associated equipment to operate in the desired manner but which does not perform any safety-instrumented functions with a claimed *SIL* (3.73) ≥ 1

[SOURCE: IEC 61511-1:2004, 3.2.3]

3.5

breakaway device

device on the *fuelling hose* (3.27) that disconnects the hose from the *dispenser* (3.13) when a tension limit is exceeded and blocks the flow of hydrogen from the dispenser, e.g. if the vehicle moves away with the fuelling hose connected to the vehicle

3.6

buffer storage vessels

pressure vessels designed for the purpose of storing compressed hydrogen, 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 *dispensing system* (3.17) for accumulation of pressurized gas supply for vehicle fuelling

3.7

building

structure, usually enclosed by walls and a roof, constructed to provide support or shelter for intended occupancy

3.8

canopy

roof, overhead shelter, or hood which affords a degree of weather protection

3.9

compressed hydrogen storage system

CHSS

hydrogen storage on-board vehicle, as defined in the GTR#13

3.10

component pressure rating

maximum pressure at which it is permissible to operate a component as specified by the manufacturer at a specified temperature

Note 1 to entry: Components designed with a maximum allowable pressure per the European PED represent the component pressure rating by the manufacturer that as indicated by the value of "PS".

Note 2 to entry: This is sometimes referred to as the *maximum allowable working pressure* (3.45) for the component, for example for vessels.

Note 3 to entry: In addition to the specification of the maximum temperature, the manufacturer can define an allowable minimum temperature or temperature range expected for service. For additional thermal conditions and risks potentially experiences during *fires* (3.23), see 5.3.6.4.

Note 4 to entry: Pressures up to 10 % above the rating can occur during fault management by PSV. See [E.3](#) regarding limited cycle testing to 110 % of the rating as part of verification testing to demonstrate capability of the component.

Note 5 to entry: See [Annex E](#) for discussion of pressure terminology and its application to *dispensing systems* ([3.17](#)) and *fuelling stations* ([3.29](#)) in general.

3.11 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: Also see *safety-instrumented system (SIS)* ([3.72](#)) and *basic process control system (BPCS)* ([3.4](#)).

3.12 connector

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

Note 1 to entry: *Fittings* ([3.24](#)) are a type of connector used in piping systems.

Note 2 to entry: Examples of connectors commonly used in hydrogen systems are as follows:

- a) The fuelling *nozzle* ([3.53](#)) "connector" mates with the *receptacle* ([3.64](#)) "connector" on the vehicle to form the connection for transfer of compressed hydrogen between the *dispenser* ([3.13](#)) and the vehicle, as defined in ISO 17268 for this specific application;
- b) The hose assemblies have connectors on each end that allow coupling to the hoses and connection to the piping system, e.g. *hose breakaway device* ([3.5](#)) or fuelling nozzle;
- c) *Control systems* ([3.11](#)) often use electrical connectors to allow rapid and secure assembly or replacement.

3.13 dispenser

equipment in the *dispensing system* ([3.17](#)), including the *dispenser cabinet(s)* ([3.14](#)) and support structure, that is physically located in the fuelling area

Note 1 to entry: The hydrogen dispenser typically includes, as a minimum, the *fuelling assembly* ([3.26](#)), required temperature and pressure instrumentation, filters, and the user interface to conduct vehicle fuelling.

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

3.14 dispenser cabinet

protective *housing* ([3.40](#)) that encloses process piping and can also enclose measurement, control and ancillary *dispenser* ([3.13](#)) equipment

3.15 dispenser fuel pressure

pressure of the hydrogen gas supplied to the vehicle by the station

Note 1 to entry: See [Annex E](#) for discussion of pressure terminology and its application to *dispensing systems* ([3.17](#)).

3.16 dispenser fuel temperature

temperature of the hydrogen gas supplied to the vehicle by the station

3.17 dispensing system

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

3.18 enclosure

structure, protective *housing* (3.40), container, machine cabinet, etc. which encloses or partially encloses equipment of a station that may have access for maintenance but is not intended to be occupied

Note 1 to entry: The use of an enclosure could be to protect equipment from the environment, provide noise attenuation, or provide *safety* (3.69) to the areas surrounding the equipment.

Note 2 to entry: A *canopy* (3.8) without walls is not regarded as an enclosure in this context.

3.19 explosion

ignition and rapid combustion that causes an over-pressure

Note 1 to entry: A rapid deflagration and/or a detonation are explosions.

Note 2 to entry: Slow deflagrations or jet flames do not create an over-pressure and are therefore not considered to be explosions.

3.20 explosive gas atmosphere

mixture with air, under atmospheric conditions, of flammable substances in the form of gas or vapour, which, after ignition, permits self-sustaining flame propagation

Note 1 to entry: Although a mixture which has a concentration above the upper flammable limit (UFL) is not an explosive gas atmosphere, it can readily become so and, generally for area classification purposes, it is advisable to consider it as an explosive gas atmosphere.

[SOURCE: IEC 60079-10-1:2015, 3.2]

3.21 factory acceptance testing FAT

tests performed in the factory on *fuelling station* (3.29) equipment or systems to verify functionality and/or integrity prior to shipment to the site, (or an appropriate alternative type acceptance methodology)

3.22 fallback

back-up control strategy, for example in the fuelling protocol when the anticipated precooling of hydrogen to within a specified range of temperatures is not achieved, however fuelling is able to continue, typically at a different fuelling rate

3.23 fire

non-premixed combustion process of a solid, liquid pool, or a jet plume of flammable substance

Note 1 to entry: A fire is the combustion of a solid or liquid of a process first of pyrolysis or evaporation to a combustible gas where a non-premixed combustion process ensues. Also, a non-premixed combustion of a flammable plume (jet fire) is also covered by this definition as is combustion of metals and of hydrogen released by a metal hydride. A fire as defined here does not create an over-pressure therefore is not an *explosion* (3.19), nor is it a deflagration or a detonation which are premixed combustion phenomena.

3.24 fitting

part or design feature on a component used to join (i.e. connect) any pressure retaining components in the system

3.25 forecourt

surfaced area where vehicle dispensing operations are conducted including the *fuelling pad* (3.28) and any area underneath a *canopy* (3.8)

3.26**fuelling assembly**

part of the *dispenser* (3.13) providing the interface between the *hydrogen fuelling station* (3.29) and the vehicle - an assembly consisting of a hose *breakaway device* (3.5), a hose(s), a *nozzle* (3.53) and connections between these components

Note 1 to entry: The fuelling assembly can include, or not, a nozzle vent line (with hose breakaway device and hose) depending on the type of nozzle, and communications, if used.

3.27**fuelling hose**

flexible conduit used for dispensing gaseous hydrogen to vehicles through a fuelling *nozzle* (3.53)

3.28**fuelling pad**

area with special construction requirements adjacent to the hydrogen *dispensers* (3.13), where customers park their vehicles during fuelling

3.29**hydrogen fuelling station****fuelling station**

facility for the dispensing of compressed hydrogen vehicle fuel, often referred to as a hydrogen refuelling station (HRS) or hydrogen filling station, including the supply of hydrogen, and hydrogen compression, storage, and *dispensing systems* (3.17)

3.30**stand-alone**

<hydrogen fuelling station or dispenser> independent for the dispensing of compressed hydrogen only

3.31**integrated**

<hydrogen fuelling station or dispenser> being part of an existing, or new build, conventional *fuelling station* (3.29) for the dispensing of compressed hydrogen

3.32**fuelling station operator**

person or organization responsible for the safe operation, maintenance and housekeeping of the *fuelling station* (3.29)

3.33**guard**

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

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

3.34**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, modified — The word "physical" has been added.]

3.35**harmonised standard**

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

3.36**hazard**

potential source of *harm* (3.34)

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

3.37

hazard distance

distance from the *hazard* (3.36) to a determined physical effect value that can lead to a range of *harm* (3.34) to people, equipment or environment

Note 1 to entry: It can be used as an input to quantitative *risk assessment* (3.66) to, for example, estimate the risk of injury or fatality to people (e.g. via probit functions).

Note 2 to entry: Hazards include, for example, physical, thermal, or pressure effects that can cause harm and can be determined by physical or numerical modelling, experience, or by a regulation.

3.38

hazardous area classified area

<explosive gas atmospheres> area in which an *explosive gas atmosphere* (3.20) is or may be expected to be present, in quantities such as to require special precautions for the construction, installation and use of equipment

Note 1 to entry: The interior of many items of process equipment are commonly considered as a hazardous area even though a flammable atmosphere may not normally be present to account for the possibility of air entering the equipment. Where specific controls such as inerting are used the interior of process equipment may not need to be classified as a hazardous area.

[SOURCE: IEC 60079-10-1:2015, 3.3.1, modified — The alternative preferred term "classified area" has been added.]

3.39

hose assembly

assembly which includes the hose and end connections, including any necessary *fittings* (3.24), bend restrictors, and appropriate markings.

3.40

housing

guard (3.33) or *enclosure* (3.18) for operating parts, control mechanisms, or other components, that need not be accessible during normal operation

3.41

hydrogen purifier

equipment to remove undesired constituents from the hydrogen

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

3.42

hydrogen service level

HSL

pressure level in MPa used to characterize the hydrogen service of the *dispensing system* (3.17) based on the *NWP* (3.51) of the vehicle.

Note 1 to entry: The numerical value of HSL also matches the number after the "H" in the *pressure class* (3.58) (see [Table 1](#)).

Note 2 to entry: See [Annex E](#) for application of pressure terminology to hydrogen dispensing systems and vehicles.

3.43

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.

3.44**lower flammable limit****LFL**

concentration of flammable gas, vapour or mist in air below which an *explosive gas atmosphere* (3.20) will not be formed

[SOURCE: IEC 60079-10-1:2015, 3.6.12]

3.45**maximum allowable working pressure****MAWP**

maximum pressure permissible in a system at the temperature specified for the pressure

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

Note 2 to entry: See [Annex E](#) for discussion of pressure terminology and its application to *dispensing systems* (3.17) and *fuelling stations* (3.29) in general.

3.46**maximum fuelling pressure****MFP**

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

Note 1 to entry: Per the GTR#13, the maximum fuelling pressure is 125 % *NWP* (3.51) (see [Annex D](#)).

Note 2 to entry: Also referred to as Maximum Fill Pressure.

Note 3 to entry: See [Annex E](#) for discussion of pressure terminology and its application to *dispensing systems* (3.17) and *fuelling stations* (3.29) in general.

3.47**maximum operating pressure****MOP**

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

Note 1 to entry: In the case of the *dispensing system* (3.17), the MOP is equivalent to the *maximum fuelling pressure* (3.46) of the vehicle.

Note 2 to entry: See [Annex E](#) for discussion of pressure terminology and its application to dispensing systems and *fuelling stations* (3.29) in general.

3.48**mitigation**

combination of the measures incorporated at the design stage and the measures required to be implemented by the station operator, *dispenser* (3.13) operator, or others involved with the operation and maintenance of the *fuelling station* (3.29) to reduce the *probability* (3.60) or severity of an *incident* (3.43)

3.49**mobile storage**

multiple-element gas container (3.50) or liquid hydrogen tank fixture mounted on a vehicle or trailer and used for the transportation of hydrogen to *hydrogen fuelling stations* (3.29)

3.50
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^[79] uses a different definition.

[SOURCE: ISO 10286:2015, 2.2.1, 210]

3.51
nominal working pressure
NWP

pressure of a vehicle *CHSS* (3.9) at 100 % *SOC* (3.78) at a gas temperature of 15 °C

Note 1 to entry: See GTR#13 clause II-3.37, on page 54.

Note 2 to entry: For road vehicles, this is typically 35 MPa or 70 MPa.

Note 3 to entry: See [Annex E](#) for discussion of pressure terminology and the correspondence between vehicle terminology and *dispensing systems* (3.17).

Note 4 to entry: Also known as “settled pressure” in ISO 10286.

3.52
non-public fuelling station

fuelling station (3.29) that does not sell or dispense gaseous hydrogen to the general public

EXAMPLE Private or municipal vehicle fleet operation.

3.53
nozzle

device connected to a fuel *dispensing system* (3.17), which permits the quick connect and disconnect of fuel supply to the vehicle storage system

[SOURCE: ISO 17268:2012, 3.8]

3.54
outdoors

location outside of any *building* (3.7) or structure, or location under a roof, weather shelter, or *canopy* (3.8) provided this area is not enclosed on more than two sides

3.55
plinth

raised area on the *forecourt* (3.25), supporting and protecting the *dispensers* (3.13) and associated equipment

3.56
positive isolation

complete separation of one part of the plant or equipment from other parts of the system

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: Physical disconnection, for example, spool removal, or use of a blind or a spade are typical ways to provide positive isolation.

Note 3 to entry: Alternatively, *proved isolation* (3.61) can be deemed acceptable based on *risk assessment* (3.66).

Note 4 to entry: Further information can be found in HSG253.

3.57**pre-cooling**

process of cooling hydrogen fuel temperature prior to dispensing

3.58**pressure class**

non-dimensional rating of components designed to dispense hydrogen to road vehicles at the required pressure and temperature

Note 1 to entry: The numbers following 'H' in the pressure class are numerically the same as *HSL* (3.42), but the HSL identifies only the level of the dispensing service whereas the pressure class designation shows the component are fully capable of meeting the pressure and temperature requirements for dispensing hydrogen at the indicated service level.

Note 2 to entry: See [Annex E](#) for discussion of pressure terminology and its application to *dispensing systems* (3.17) and *fuelling stations* (3.29) in general.

Note 3 to entry: Additional examples of pressure class come from ISO 15649; e.g. "600", "3000" or "6000".

3.59**pressure relief device****PRD**

safety (3.69) device that releases gases or liquids above a specified pressure value in cases of emergency or abnormal conditions

Note 1 to entry: PRDs can be activated by pressure or another parameter, such as temperature, and can 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 rupture and re-closes when the pressure falls below the set point. Requirements for PRVs used in *dispensing systems* (3.17) can be found in [8.2.2.3](#). PSVs protecting the dispensing system can reclose above the *MOP* (3.47).
- Thermally-activated pressure relief device (TPRD) — a PRD that opens at a specified temperature to protect a system from rupture and remains open.

Note 2 to entry: See [Annex E](#) for discussion of pressure terminology and its application to pressure protection of the dispensing system and *fuelling stations* (3.29) in general.

3.60**probability**

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

3.61**proved isolation**

valved isolation where the effectiveness of valves closure can be confirmed via vent or *bleed* (3.3) points

Note 1 to entry: Proved isolation can often be used instead of *positive isolation* (3.56), where this is deemed acceptable based on *risk assessment* (3.66).

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

Note 3 to entry: Further information can be found in HSG253.

3.62**public fuelling station**

fuelling station (3.29) that sells gaseous hydrogen to the general public

3.63

qualified personnel

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

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

3.64

receptacle

device connected to a vehicle storage system which receives the *nozzle* (3.53)

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

[SOURCE: ISO 17268:2012, 3.11]

3.65

risk

combination of the *probability* (3.60) of occurrence of *harm* (3.34) and the severity of that harm; encompassing both the uncertainty about and severity of the harm

[SOURCE: ISO/IEC Guide 51:2014, 3.9, modified — The part "encompassing both the uncertainty about and severity of the harm" has been added; Note 1 to entry has been removed.]

3.66

risk assessment

determination of quantitative or qualitative value of risk related to a specific situation and a recognised threat (also called *hazard* (3.36))

Note 1 to entry: Based on national requirements, a review of a risk analysis or a *safety* (3.69) concept by third party is sometimes required.

3.67

risk level

assessed magnitude of the risk

3.68

safeguarding

instruments or final elements related to *safety-instrumented system, SIS* (3.72), or *pressure relief device, PRD* (3.59)

Note 1 to entry: Safeguarding can be instrumental safeguarding or mechanical safeguarding.

3.69

safety

freedom from unacceptable risk

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

3.70

safety distance

separation distance

safe distance

setback distance

distance to acceptable *risk level* (3.67) or minimum risk-informed distance between a *hazard* (3.36) source and a target (human, equipment or environment), which will mitigate the effect of a likely foreseeable *incident* (3.43) and prevent a minor incident escalating into a larger incident

Note 1 to entry: Safety distances could be split into Restriction distances, Clearance distances, Installation layout distances, Protection distances and External risk zone. See A.5.2 for further details.

3.71**safety function**

function to be implemented by a *safety-instrumented system* (3.72), 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 safety-instrumented system, however validation of these measures is equally important.

3.72**safety-instrumented system****SIS**

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

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

Note 2 to entry: A separate safety-instrumented system (SIS), typically with a greater reliability than the more *basic process control system (BPCS)* (3.4), can be required, according to the manufacturer's *risk assessment* (3.66), to respond solely to safety critical alarms. Further information is provided by IEC 61508 and IEC 61511.

3.73**safety integrity level****SIL**

discrete level (one out of a possible four), corresponding to a range of safety integrity values, where safety integrity level 4 has the highest level of safety integrity and safety integrity level 1 has the lowest

Note 1 to entry: The target failure measures (see IEC 61508-4) for the four safety integrity levels are specified in IEC 61508-1:2010, Tables 2 and 3.

Note 2 to entry: Safety integrity levels are used for specifying the safety integrity requirements of the *safety functions* (3.71) to be allocated to the *E/E/PE safety-related systems* (3.74).

Note 3 to entry: A safety integrity level (SIL) is not a property of a system, subsystem, element or component. The correct interpretation of the phrase "SIL n safety-related system" (where n is 1, 2, 3 or 4) is that the system is potentially capable of supporting safety functions with a safety integrity level up to n.

Note 4 to entry: See 8.2.

[SOURCE: IEC 61508-4:2010, 3.5.8, modified — Note 4 to entry has been added.]

3.74**safety-related system**

designated system that both implements the required *safety functions* (3.71) 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* (3.36) or hazards. Although there can 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* (3.11) 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* (3.73) 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 can 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).

3.75 site acceptance testing

SAT

tests performed after installation of the *fuelling station* (3.29) at the site to verify functionality and/or integrity

3.76 skid

process system contained within a frame that allows the process system to be easily transported and installed for operation

3.77 standards development organization SDO

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

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

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

3.78 state of charge SOC

density (or mass) ratio of hydrogen in the *compressed hydrogen storage system (CHSS)* (3.9) between the actual CHSS condition and the capacity at *NWP* (3.51) when the system is equilibrated at 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.

Note 3 to entry: (%) can be calculated as follows:

$$\frac{\rho_1}{\rho_2} \times 100$$

where

ρ_1 is the density of hydrogen under the specific gas conditions;

ρ_2 is the density of hydrogen at the nominal working pressure at a gas temperature of 15 °C.

The hydrogen densities at the two major nominal working pressures are:

- density of H₂ at 35 MPa and 15 °C = 24,0 g/l
- density of H₂ at 70 MPa and 15 °C = 40,2 g/l

Note 4 to entry: The ρ_1 function for hydrogen is available from the National Institute of Standards and Technology (NIST) at <https://nvlpubs.nist.gov/nistpubs/jres/113/6/V113.N06.A05.pdf>.

3.79

target pressure

dispenser ([3.13](#)) fuel pressure that the hydrogen fuelling protocol targets for the end of fuelling

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

3.80

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

3.81

maximum developed pressure

maximum accumulated pressure

highest pressure expected during fault management by the *dispensing system* ([3.17](#))

Note 1 to entry: Per the GTR, the maximum developed pressure is $1,50 \times \text{NWP}$. See [Annex D](#).

Note 2 to entry: The estimate of maximum developed pressure is based on a “worst case” assumptions — the highest possible setpoint for the pressure protection and maximum allowable values for setpoint accuracy and “lift” to open the PSV for full relieving.

4 Abbreviated terms

AiCHE	American Institute of Chemical Engineers
ALARP	as low as reasonably practicable
API	American Petroleum Institute
APRR	average pressure ramp rate
CABF	conformity assessment bodies forum
CENELEC	French: Comité Européen de Normalisation Électrotechnique (European Committee for Electrotechnical Standardization)
CFD	computational fluid dynamics
CGA	Compressed Gas Association
DDT	deflagration to detonation transition
E/E/PE	electrical/electronic/programmable electronic
ERP	emergency response plan
ESReDA	European Safety, Reliability and Data Association
ETSI	European Telecommunications Standards Institute
EUC	equipment under control
FCEV	fuel cell electric vehicle
FEMA	failure modes and effects analysis
H35	indication for 35 MPa NWP hydrogen fuelling as defined in ISO 17268

H70	indication for 70 MPa NWP hydrogen fuelling as defined in ISO 17268
HAZOP	hazard and operability study
HSG	health and safety guidance
IrDA	Infrared Data Association
LFL	lower flammability limit
MEGC	multiple element gas containers
OREDA	offshore and onshore reliability data
P&I	piping and instrumentation
P&ID	piping and instrumentation diagram
PELV	protective extra-low voltage
PFP	passive fire protection
PLC	programmable logic controller
PPE	personal protective equipment
PSV	pressure safety valve
QRA	quantitative risk assessment
RoHS	restriction of hazardous substances
SAE	Society of Automotive Engineers
SELV	safety extra-low voltage
SIF	safety-instrumented function
TPRD	temperature-activated pressure relief device

5 Risk management

5.1 Hydrogen fuelling station safety recommendations

The hydrogen fuelling station installation should be sited to minimise risk to users, operating personnel, properties, and the environment to an acceptable level.

The following elements of a hydrogen fuelling station shall be considered potential hazard sources:

- on-site hydrogen production unit as applicable;
- hydrogen delivery system, including mobile storage and remote fill points as applicable;
- compressors;
- storage;
- piping connections (non-welded);
- dispensers.

The hydrogen fuelling station shall include measures to reduce the risk of harm from fires, deflagrations, detonations and blast waves to an acceptable level.

Example mitigation strategies are covered in greater detail in the [5.3](#) and [5.4](#).

Hazards on the fuelling station unrelated to hydrogen fires shall also be addressed (if applicable). An example list can be found in [5.5](#).

5.2 Risk assessment

Risk assessment is the overall process of risk identification, risk analysis, risk evaluation, and risk mitigation. Use of risk assessment may allow station owners and designers to flexibly define station-specific mitigations that achieve an equal or better level of risk to those of prescriptive recommendations or to relax existing prescriptive mitigation measures as long as the total system risk remains below the selected tolerability threshold (risk acceptance criteria).

A risk assessment shall be performed for the hydrogen fuelling station except when the stations comply with prescriptive regulations that address relevant risks. See standards such as ISO 31000, IEC 31010, and/or ISO 12100 for guidance in conducting risk assessment. The risk assessment should demonstrate that the mitigation measures employed are appropriate to achieve the desired level of risk of the station (see [Clause 11](#)).

It is recommended that the risk assessment carried out for the hydrogen fuelling station should be quantitative or semi-quantitative. Further recommendations for semi-quantitative or quantitative risk assessment of hydrogen fuelling stations can be found in [Annex A](#).

NOTE 1 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 [A.1](#).

NOTE 2 An example of a quantitative risk assessment toolkit to facilitate the performance of a specific station is given in [A.2](#).

NOTE 3 [Annex B](#) includes the recommendations generated from an example fuelling process risk assessment.

If a quantitative risk assessment (QRA) is used, non-hydrogen hazards, as defined in [5.5](#), shall be covered.

5.3 Mitigation measures to improve system safety

5.3.1 General

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.

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.

5.3.2 Mitigations which reduce the potential for the formation of a flammable mixture

5.3.2.1 General

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

Examples on how to reduce the potential for the formation of a flammable mixture can be found in [Annex B](#).

5.3.2.2 Safety and emergency shut-off systems

In order to minimise the magnitude of an unintentional release, or to minimise the duration of the flammable mixtures, isolation valves that can shut-off the hydrogen supply from the hydrogen storage to other areas of the hydrogen fuelling station shall be installed (see [11.2](#)).

The position to which automatic valves in hydrogen lines move in the event of power or pneumatic pressure loss should be defined by risk assessment and implemented accordingly.

5.3.2.3 Pressure relief devices for gaseous hydrogen systems

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

Over-pressure protection shall be set at, or below, the MAWP of the pressure system that it is protecting.

The MAWP of the system shall not be greater than the lowest component pressure rating in the system.

A PRD can be of the resealable type, such as spring-loaded pressure actuated safety valves (PSVs), or of the non-resealable pressure actuated safety device (PSD) type, such as rupture disks and diaphragms (see [7.2.2](#)). The risk associated with non-reclosing types of PRDs should be considered in the design and layout of the station (see [7.8](#)).

The equipment should be protected against excessive pressure at all times. Consideration should be given in the design of the installation to facilitate the periodic testing and maintenance of the PRDs (see [15.4](#)).

NOTE EN 764-7 provides guidance on the isolation of relieving safety systems.

5.3.3 Mitigation for the formation of a flammable mixture in enclosures

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

[Annex B](#) gives examples on how this can be achieved; associated requirements can be found in [7.11](#).

NOTE 1 When this is not practical, see [7.4](#) for guidance on classifying hazardous areas and controlling ignition sources within the hazardous area.

NOTE 2 Sudden and catastrophic failure of vessels or piping systems doesn't need to be considered in this analysis when protection against such failures has already been contemplated in the vessel and piping design.

Area classification determined as per [7.4](#) and the protection recommendations for equipment in hazardous 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 and mechanical apparatus operating in dilution volume that can exist near potential sources of release (leaks points) should be protected in accordance with [7.4](#).

Enclosures should be designed so as to minimise high points (or locally high points) where hydrogen can accumulate.

Flows from vents and safety relief equipment shall be piped to an appropriate location. See [5.4.2](#) for further information.

5.3.4 Mitigation for the formation of a flammable mixture under a canopy

The formation of hazardous atmospheres resulting from anticipated hydrogen leaks or releases under canopies should be minimised when practical.

NOTE When this is not practical, see [10.2](#) for guidance on classifying hazardous areas and controlling ignition sources within the hazardous area.

Area classification determined as per [10.2.2](#) and the protection recommendations for equipment in hazardous areas may be adjusted taking into account the availability 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](#).

Where the hazardous area above a dispenser or other hydrogen installation reaches up to a canopy, the canopy shall be designed to prevent the accumulation of hydrogen in pockets or between the canopy ceiling and roof, unless other means of protection have been taken.

Canopies should be designed so as to minimise high points where hydrogen can accumulate.

5.3.5 Mitigations which reduce the potential for ignition

5.3.5.1 General

Measures can be taken to reduce the potential for ignition. See [7.4](#), [7.11](#) and [10.2](#) for requirements, and [Annex B](#) for examples.

5.3.5.2 Areas subject to restriction of activity

Equipment or areas of the hydrogen fuelling station in which flammable materials are handled or stored shall be designed, operated, and maintained so that any releases of flammable material, and consequently the extent of potentially flammable 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 shall be taken:

- minimise the likelihood of an explosive gas atmosphere occurring around the existing sources 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 electrical and mechanical equipment should be appropriately classified (see [7.4](#) and [7.4.2](#)).

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 trained and aware of the hazards potentially encountered and the relevant emergency procedures.

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

All portable equipment which can 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.

Requirements for grounding and bonding to prevent electric shock and electrostatic discharge are provided in [10.1.3](#) or [10.2.3](#) as applicable.

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

5.3.6.1 General

A list of possible mitigations is provided in [Annex B](#).

5.3.6.2 Flame or fire detection systems

Where identified by the hydrogen fuelling station risk assessment, direct or indirect means of detection of hydrogen fires should be provided to avoid escalation due to flame impingement on neighbouring equipment by taking an appropriate action.

When detection equipment is used, this shall be set up in such a way that its functionality can be easily inspected.

5.3.6.3 Over-pressure protection of enclosures and buildings containing hydrogen systems

Enclosures and buildings containing hydrogen systems or other flammable systems shall comply with [7.11](#).

A risk assessment shall be conducted on enclosures and buildings containing hydrogen systems to determine the need for over-pressure protection. The risk assessment shall consider potential leak rate(s) and their frequency, extent of formation of flammable mixtures within the enclosure with consideration of ventilation, possibility of ignition, and the resultant over-pressure due to either high flow rate from pressurized systems or the ignition of flammable mixtures, including the effect of the pressure peaking phenomenon.

Where required by the risk assessment, enclosure design shall address either withstanding or venting over-pressure events as defined in [7.11.6](#).

NOTE Such analysis can necessitate the use of CFD, for further guidance, see NFPA 68, and for examples of CFD tools, see [A.4.2](#).

If venting is required for over-pressure protection, then the risk assessment needs to be extended to determine the necessary area of vent openings in exterior walls or the roof of the enclosure or building.

Over-pressure venting shall be provided in exterior walls or the roof, and may 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 and possibly flying projectiles outside the opening shall be considered by risk assessment.

5.3.6.4 Emergency release of gas from hydrogen storage vessels under fire conditions

If hydrogen storage vessels are exposed to fire conditions (from inside or outside the storage area or compartment) that could lead to rupture, the station risk assessment should consider the need for thermally or pressure activated (non-reclosing) and/or manually activated valves to safely vent all the

content of the hydrogen storage (see 7.8). Where such a valve needs manual activation, this should be possible from an appropriate location.

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

5.3.7.1 General

Measures should be taken to minimise the effect of events that have potential to take place in the vicinity of the fuelling station. A list of example measures can be found in [Annex B](#).

5.3.7.2 Layout

The layout of a hydrogen fuelling station shall reduce to an acceptable level the likelihood of damage or injury 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.

The general layout of installations for the storage, processing, and delivery of hydrogen should allow unhindered access and exit for the fuelling station operator, maintenance personnel, suppliers, and emergency services as appropriate.

Attention shall be paid to:

- good overview of the installation for the operating staff both from the operating building (if applicable) and from the hydrogen delivery installations;
- clear arrangement of access roads, exits and site surfacing with a view to collision hazards;
- accessibility to the installation in case of fighting any fire;
- evacuation facilities in case of incidents.

Installations should be kept free of vegetation debris and other flammable materials.

No flammable liquids shall be able to accumulate under the hydrogen storage vessels.

5.3.7.3 Fire barrier recommendations

A fire barrier may be used as a mitigation option to reduce safety distances. A list of possible mitigation measures can be found in [Annex B](#).

If a fire barrier is used as a mitigation option, it shall be made of appropriately fire-resistant materials.

NOTE There are no appropriate ISO testing documents that cover this topic for hydrogen combustion (flames). ISO 22899-1 and ISO 834-1 include guidance on how to measure the fire resistance, however, ISO 22899-1 was derived for highly sooty and thus highly radiative hydrocarbon combustion. Hydrogen combustion does not produce soot and thus are weakly radiating compared to hydrocarbon combustion. Hence, the testing defined in ISO 22899-1 can over predict the heat load, thus represent a very conservative test, resulting in an overly designed barrier.

Consideration should be taken for the overpressure effects generated around the barrier by an unignited or ignited release. Walls intended as mitigation against fires or 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 (see 5.3.7.6).

5.3.7.4 Mitigating against vehicular impact

Hydrogen storage and dispensers should not be located in a direct line of traffic, e.g. entrance or exit to station, or should be suitably protected against vehicular impact. The fuelling station operator shall assess impact hazards in the fuelling station risk assessment, and vehicular impact protection should be appropriate for the anticipated type and speed of vehicles in the vicinity of the hydrogen equipment.

NOTE 1 Further guidance on the protection of dispensers from vehicle traffic is included in [Annex G](#).

NOTE 2 Plinths of adequate height and bollards of sufficient strength strategically placed are techniques typically used.

The station design shall minimise the need for vehicle manoeuvres in order to reduce to an acceptable level 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.

If deemed appropriate or necessary by risk assessment, vehicular impact protection should be supplemented by the dispensing system control protection defined in [8.2.2.8](#) that detects physical disturbance of the dispenser, for example by vehicle collision.

Procedural measures or vehicular impact protection should be considered to protect delivery vehicles as appropriate.

5.3.7.5 Firefighting systems

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

Where water is required for firefighting, this shall be 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 firefighting purposes, suitable fire-extinguishing appliances shall 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 while allowing a release to persist. The escaping hydrogen should be shut off where possible. 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 a flammable mixture. 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 rupture of the vessels. Water from the firefighting system should not be directed at or introduced into a hydrogen system vent stack. After a fire, the hydrogen system vent stack(s) should be drained of any accumulated water and inspected for damage prior to release for use.

5.3.7.6 Emergency principles and operations

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

The installation shall be designed so that authorised personnel have easy access at all times and have adequate means of escape in the case of emergency. Access to critical equipment (for example, operating valves) shall be restricted to authorised persons. Emergency exits shall 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 shall be 0,8 m. Timber or other readily combustible materials shall not be used for fencing.

The gates shall be wide enough to provide for easy access and exit of authorized personnel. Gates shall 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. The fast release shall not be accessible from outside of the fence.

Consideration shall 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 fenced areas, there shall be at least two separate outward opening points of egress, remote from each other, that are strategically placed in relation to the hazard considered.

Full emergency procedures shall be established for each particular fuelling station in consultation with local fire authorities.

Where critical hydrogen equipment can be exposed to fires, which may originate from non-hydrogen related equipment, at least one of the following safety systems should be considered:

- a) water sprinklers or remote watering system for cooling of equipment exposed to fire (see [5.3.7.5](#));
- b) means for the emergency venting of hydrogen storage vessels as per [5.3.6.4](#).

5.3.8 Mitigation of risk to the high pressure hydrogen storage system of the vehicle being fuelled

Adequate measures shall be taken to reduce the risk of subjecting the vehicle high pressure hydrogen system to unsafe conditions, such as those outside of the operating range defined in GTR#13 (see [8.2](#) and [Annex E](#)).

A risk assessment shall establish the level of safeguarding needed to address the limits outlined in [8.2.1](#).

5.4 Safety distances

5.4.1 General

The hydrogen fuelling station layout shall incorporate adequate safety distances. 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 (considering all mitigation and safety measures implemented). 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 An example of safety distance definitions is given in [A.5](#).

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 can be prescribed by national regulations, 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 recalculated 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.

NOTE 3 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 toolkit, preferably validated for hydrogen, is recommended.

NOTE 4 Examples of safety distance toolkits are given in [Annex A](#). One such toolkit has been used to prepare a series of example risk assessments to iteratively determine safety distances for example fuelling stations with varied country specific inputs (see [A.6](#)).

5.4.2 Safety distances relating to hydrogen vent stack outlets

The vent outlet location (height; distance to exposures) shall 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 expected wind conditions. The safety distances for vented gas from liquid hydrogen systems shall take into consideration the density of the gas.

The thermal radiation and overpressure effects of ignited vented gas (immediate or delayed ignition) shall 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 risk assessment.

NOTE 1 Calculations can be performed according to the risk assessment toolkits detailed in [A.4](#).

NOTE 2 See [7.8](#) for further requirements relating to hydrogen vent stacks.

5.5 Protection measures for non-hydrogen hazards

5.5.1 General

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

- working at heights (see [7.3.3.4](#));
- asphyxiation (see [5.5.2](#));
- emergency egress routes out of enclosures or vaults (see [5.5.3](#));
- electrocution (see [10.1](#));
- moving machinery (see IEC 60204-1);
- anti-whip measures for hoses (see [5.5.5](#));
- noise (see [5.5.6](#)).

Additional examples of non-hydrogen hazards typically encountered at fuelling stations are listed in [B.5](#). These hazards, as well as any other hazards unique to a particular fuelling station system or site should be considered and addressed when appropriate.

5.5.2 Protection measures for asphyxiation hazard in an enclosure (confined space)

When an enclosure is intended to be entered and contains or is connected to a source of hydrogen or inert gases, that compartment shall 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 shall be put in place to prevent this occurring while personnel are present in or entering into the compartment, or detection and notification appliances shall be provided to warn personnel of an oxygen-deficient atmosphere.

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

Where portable detection and notification appliances are used, a means of testing the gas composition inside the container (main enclosure) without opening the container door should be provided. This can be, for example, a set of external connection points to attach a gas detector sensitive to oxygen concentration (asphyxiation), hydrogen concentration (flammable mixtures), and, if necessary, other constituents likely to be present in the process. These external connection points should be routed inside the container to locations where these constituents would be likely to be present.

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

5.5.3 Protection measures for emergency egress from enclosed spaces

Exterior access doors should be secured against unauthorized entry.

NOTE 1 This can be done globally by securing the perimeter fence access, or locally by securing the enclosure(s). Refer to IEC 60204-1, the national electrical code and/or the national occupational safety code for local requirements.

Locks or latches on emergency doors shall not require the use of a key or a tool for the operation from the egress side. Where access into enclosed spaces e.g. equipment containers or vaults (see [7.3.3.3](#)) is possible, a personnel access way with adequate space to ensure a permanent escape route shall be provided. The travel distance from points of maintenance inside an enclosed space to an emergency egress point should be appropriately minimised to be consistent with risk assessment, otherwise multiple means of egress should be provided.

NOTE 2 Egress recommendations are not applicable when all operation and maintenance-related work is performed from the exterior of the enclosure.

5.5.4 Ingress protection measures

The potential hazards and risks due to ingress of water, dirt/dust, or people into enclosures shall be assessed. If such potential hazards or risks exist, then, according to [7.11](#), the enclosure shall meet appropriate measures of IEC 60529 to mitigate these hazards and risks. The rating shall be verified per the test methods in IEC 60529.

NOTE 1 Components and equipment individually protected to the levels defined by this assessment do not need to be enclosed, and subsequently enclosures not intended to provide weather and personnel protection can be exempt from meeting an 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.

5.5.5 Protection measures for hose whip

For working pressures in excess of 4 MPa, hoses assembled shall 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. Guidance is available from 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 [8.2.2.5](#)) may be used in place of restraining devices where appropriate.

5.5.6 Protection measures for noise

It is presupposed that the sound pressure level and sound power level under normal operating conditions do not exceed relevant local limitations. Events such as the opening of a relief valve, or separation of the hose break-away device in the case of a drive-away event, etc. are not considered normal operation.

5.5.7 Protection against exposure to extremely cold or hot temperatures

Processes within the hydrogen fuelling station may operate at extremely cold temperatures or very hot temperatures.

Liquid hydrogen storage and processing systems operate below $-250\text{ }^{\circ}\text{C}$, and hydrogen dispensing system precooling systems (including refrigerant systems, if used) typically operate at temperatures below $-40\text{ }^{\circ}\text{C}$. Conversely, hot surfaces may be encountered on processing equipment (i.e., compressors and pumps) or due to solar exposure.

In addition to possible exposure of workers during maintenance, the risk to the general public in the dispensing area shall be assessed, particularly with fuelling assembly which is handled as part of vehicle fuelling. If people come in contact with surfaces at these extremely cold temperatures, injury may occur, so this potential hazard shall be considered as part of the risk analysis.

NOTE See ISO 13732 for further guidance.

Examples of countermeasures to prevent exposure to cold temperatures are (but not limited to) the following:

- a) protective coverings or insulation on piping or components with cold surfaces;
- b) fences, guards, cabinets, or enclosures on hydrogen systems operating at cold temperatures;
- c) appropriate PPE (gloves, etc.) for workers;
- d) signage, as appropriate (see [13.2](#)).

6 Hydrogen supply safety and operation

6.1 On site generation

6.1.1 Hydrogen generators using water electrolysis

Hydrogen generators using water electrolysis shall be installed according to the manufacturer's instructions and should comply with ISO 22734 or be designed in accordance with a suitable national/regional standard(s).

6.1.2 Hydrogen generators using fuel processing technologies

Hydrogen generators using fuel processing technologies, including ancillary hydrocarbon storage and pipework, shall be installed according to the manufacturer's instructions and should meet the requirements of ISO 16110-1 and references therein, or be designed in accordance with a suitable national/regional standard(s).

Storage of hydrocarbon fuels shall 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.

6.2 Hydrogen delivery

6.2.1 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 shall support the front and rear ends of the tube trailer or MEGC in a designated area or unloading bay. The area shall be kept free of vegetation, debris, and combustible materials.

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 bump stop, such as lintels, or equivalent shall indicate normal tube trailer or MEGC position in the unloading bay when a driver needs to reverse into the bay.

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. 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 shall be accessible only to authorized persons.

Means to bond tube trailers and MEGCs to the same potential as the fixed storage hardware shall be provided (see [10.2.3](#)).

When the offloading hose(s) is disconnected, any gaseous hydrogen released shall be discharged through a vent stack to an appropriate location.

The delivery of gaseous hydrogen shall follow a pre-defined, written procedure.

NOTE Examples of gaseous hydrogen delivery procedures are included in the document PGS35.

A risk assessment of the hydrogen delivery process shall be carried out (see [5.2](#)). As a minimum, the risk assessment should consider:

- the need for an emergency shutdown system that can stop the filling process once activated, including the need for interaction with air driven valves on the tube trailer as applicable;
- emergency procedures required during the delivery process;
- the need to preclude access to the public during deliveries;
- the need for isolation valves at the fill point;
- measures taken for the prevention of over-pressurisation of the hydrogen storage;
- the design of the connection points to ensure proper connection/disconnection between the transport storage and the site storage;
- detectability of leaks during the delivery process;
- measures taken for the protection against hose rupture during transfer (see [5.5.5](#));
- the need for hazardous areas in and around the delivery area (see [7.4](#));
- control of the hydrogen flow rate, if applicable; and

— the need for appropriate signage during the filling process, and at the fill connection point (see [13.2](#)).

6.2.2 Liquid hydrogen supply by tanker

6.2.2.1 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.

Above ground liquid hydrogen storage and related equipment shall be located in a well-ventilated area to minimise the consequence of an accidental leakage. If any protective structures are used to reduce the safety distances, they shall be designed to avoid escalation of an ignited hydrogen release. The consequences on overpressure in case of ignition and deflagration to detonation transition (DDT) should be assessed.

Underground liquid hydrogen storage and related equipment shall require additional measures 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.

Means shall 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, shall not be installed above asphalt surfaces or other combustible materials in order to prevent contact of liquid air with such materials. For the purposes of this document, asphalt and bitumastic paving shall be considered combustible. If expansion joints are used, fillers shall also be made of non-combustible materials. Drip pans may be installed under uninsulated piping and equipment to retain and vaporise condensed liquid air.

Surfaces located under all uninsulated pipe and pump connections carrying hydrogen at cryogenic temperature with the possibility of air condensation shall be constructed of non-combustible materials as per [7.2.2](#).

6.2.2.2 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 shall meet the material requirements of the equipment and component standards specified in [7.1.2](#). Guidance for material compatibility in cryogenic service is given in ISO/TR 15916, ISO 21010 or ISO 21028-1.

6.2.2.3 Liquid hydrogen transfer area

The delivery of liquid hydrogen shall follow a pre-defined procedure.

NOTE An example of a liquid hydrogen delivery procedure is included in the document PGS35.

The liquid hydrogen transfer area shall be clearly defined.

Means to bond liquid hydrogen delivery vehicles to the same potential as the fixed storage hardware shall be provided (see [10.2.3](#)).

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

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

A risk assessment of the hydrogen delivery process should be carried out (see [5.2](#)).

The risk assessment should consider:

- the need for an emergency shutdown system that can stop the filling process once activated;
- emergency procedures required during the delivery process;
- the need to preclude access to the public during deliveries;
- the need for isolation valves at the fill point;
- measures taken for the prevention of over-filling or over-pressurisation of the liquid hydrogen storage;
- safe connection/disconnection of the filling hose(s); and
- the need for appropriate signage during the filling process, and at the fill connection point (see [13.2](#)).

6.2.2.4 Tank foundation and supports

Where liquid hydrogen storage tanks are required to be elevated, the tank supports shall be non-combustible structures, with an appropriate fire resistance according to risk assessment or local requirements, capable of withstanding damage by cryogenic liquid spillage.

The foundation supporting the liquid hydrogen storage tanks shall be designed to prevent pooling of liquid hydrogen or any other liquid fuel under the tank.

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

The foundation on which the liquid hydrogen storage tank is installed shall be made of concrete or any other suitable non-combustible material. The risk assessment should consider the need to direct a leak away from areas that could increase the hazard (for example buildings, occupied areas, or sewers).

The tank(s) shall be secured to the foundation, with the foundation and supports able to withstand the forces that can be anticipated for the location.

NOTE National regulations can request that the design and implementation of the foundation be reviewed and/or inspected by a third-party prior to operation.

6.2.2.5 Liquid hydrogen delivery lines

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

Liquid hydrogen delivery lines shall 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 shall be provided.

The location of safety shut off valves in liquid hydrogen service shall 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(s) is connected shall be provided.

6.2.2.6 Piping, fittings, valves, regulator for cryogenic service

Valves used for cryogenic service should comply with ISO 21011.

6.2.2.7 Pressure relief devices

Liquid hydrogen systems and equipment shall be protected from over-pressure e.g. by use of one or more PRD(s), or by other appropriate means (see [7.2](#)).

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

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

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

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

Pressure relief devices and vent piping shall be designed or located so that moisture cannot collect and freeze in a manner which would interfere with proper operation of the pressure relief device. Vent piping shall meet the requirements of [6.2.2.10](#).

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 shall 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 inspection and testing of the pressure relief devices.

6.2.2.8 Cryogenic pumps

Each cryogenic pump shall 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 shall 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.

6.2.2.9 High pressure vaporizer

The vaporizer and its piping shall 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 shall 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 shall be indirectly supplied utilising media such as air, steam, water, or water solutions.

Means to stop flow when a low temperature downstream of the vaporizer is detected shall be installed.

The vaporizer shall be anchored or secured, for example with sliding supports. Connecting piping and supports shall be designed to provide the flexibility needed to absorb the effects of expansion and contraction due to temperature changes.

Suitable means shall 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. A device should be fitted after the hydrogen vaporizer to avoid high pressure gaseous hydrogen back flow into the liquid 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.

6.2.2.10 Venting from a liquid hydrogen system

All vents, including those of pressure relief devices and purge valves shall be connected to a vent stack, refer to [7.8](#).

The various vents from the liquid hydrogen system may be connected, but connection to vents from other systems shall be avoided to prevent any back-feed from other systems into the liquid hydrogen system.

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 shall be accounted for.

Cold hydrogen vents from liquid hydrogen storage systems, including possibly the liquid delivery tanker, may be connected as long as properly sized per [7.8.2](#) with consideration of possible flow from more than one source.

6.2.2.11 Purging

Cold sections (i.e. below the boiling point of nitrogen) of liquid hydrogen installations and transfer hoses should be purged with warm (i.e. above the boiling point of nitrogen) hydrogen or warm 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.

6.3 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 or deodorisation equipment.

NOTE 1 The interface between the hydrogen pipeline and the fuelling station is typically located within the fuelling station boundary.

The hydrogen installation shall comply with the connection conditions of the gas supply company/the pipe network operator as applicable.

Interconnecting piping systems between the pipeline and fuelling station shall meet ISO 15649 or local/state piping code.

NOTE 2 See [Clause 7](#) for further information.

7 Equipment and Components

7.1 General recommendations

7.1.1 Hydrogen materials

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

Components that may need to be dismantled for maintenance should be installed in such a manner that dismantling 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.

The ability to carry out maintenance using positive or proved isolation (see [3.56](#) and [3.61](#)), should be considered in the design of the hydrogen installation.

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.

Valves, instruments and other equipment requiring servicing shall not be buried, and when installed underground, shall be accessible.

Isolation valves shall 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 shall 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, purge systems with inert gas for maintenance (when appropriate), and purge with hydrogen after maintenance shall be provided.

A standard operating procedure shall ensure 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 [Clause 9](#) before restarting dispensing operations.

7.1.2 Material hydrogen compatibility

The materials (steels, aluminium and polymers, etc.) utilized shall be compatible with hydrogen at the temperatures and pressures utilized. Due consideration shall 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, ISO 11114-1 and ISO 16573. 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 porosity of the material making permeation of hydrogen through the pipe and fittings a possibility.

Materials used for equipment containing liquid hydrogen shall comply with [6.2.2.2](#).

Vent lines, where pressurised hydrogen is not expected to be present under normal operating conditions, may use other materials not suitable for hydrogen service.

7.1.3 Other material recommendations

It is presupposed that material selection is made in accordance with local environment requirements, avoiding the use of the materials listed in the Directive 2011/65/EU (RoHS).

Care should be taken to prevent contact between dissimilar metals to prevent galvanic corrosion. Metal fittings should be compatible with metal tubing materials.

7.2 Piping carrying hydrogen

7.2.1 General

Piping used to transport hydrogen in the fuelling station shall conform with ISO 15649, or with a national/regional standard, such as a Harmonised standard, and be suitable for the anticipated cycle life. See [8.3](#) for operating requirements of piping in dispensing systems and dispenser fuelling assemblies. Piping shall be made of materials compatible with hydrogen service (see [7.1.2](#)).

When required, high pressure systems shall be protected against over-pressure by pressure relief devices (PRDs) or an equivalent measure (such as an instrumental safeguarding system with an appropriate SIL level) in accordance with ISO 15649 (or the selected piping standard). See [Clause 5](#) relative to the identification of over-pressurization risks, [7.2.1](#) for the selection of PRDs in gaseous hydrogen systems, and [7.8](#) for the design of PRD venting systems.

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

High pressure piping shall be welded in accordance with ISO 15649 or 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.

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

7.2.2 Pipe fittings, valves, hoses, for gaseous hydrogen

The rating of pipe fittings, valves, and hoses in gaseous hydrogen systems of the fuelling station shall be consistent with its use in the piping system (as defined in [7.2](#)). See [8.3](#) for operating requirements of dispensing systems and dispenser fuelling assemblies. Materials shall be compatible with hydrogen service (see [7.1.2](#)).

PSVs should meet the requirements of ISO 4126-1 or an equivalent national/regional standard.

Non re-closing safety devices should meet the requirements of ISO 4126-2 or an equivalent national/regional standard.

See the following documents for guidance in qualifying components for high pressure hydrogen service:

- ISO 19880-3 for valves and hose breakaway devices;
- ISO 19880-5 for hoses.

The testing specified in the above documents may be waived when sufficient evidence exists that the component is acceptable for service in accordance with ISO 15649 (or selected piping standard being used).

Valve assemblies shall comply with [7.4.2](#).

Piping, fittings, valves, and regulators for cryogenic service shall comply with [6.2.2.6](#).

7.3 Hydrogen storage recommendations

7.3.1 General

Liquid hydrogen delivery and storage system requirements are defined in [6.2.2](#), and gaseous hydrogen storage requirements are defined below.

7.3.2 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 vessels of different design pressures are interconnected, they shall be protected in such a way that vessels rated for a lower pressure cannot be over-pressurized due to any malfunction.

The design of the buffer storage installation shall include appropriate means to prevent failure in the case of fire when deemed necessary by risk assessment. Suitable prevention methods may include one or more of the following:

- product venting systems, such as thermally activated pressure relief devices (TPRDs);
- thermal shielding or fire barrier;
- inability for a flammable liquid to pool under the vessel;
- fixed firewater protection.

NOTE 1 Composite storage vessels can require increased protection compared to metallic vessels.

The vessel(s) shall be secured to the foundation, with the foundation and supports able to withstand the forces that can be anticipated for the location.

The layout design of the gaseous hydrogen buffer storage vessels and piping shall consider the risk from direct impingement of jet flames from potential leak points or vents onto an adjacent vessel. The station risk assessment shall include mitigation considerations about deflagration to detonation transition (DDT) in the compressed hydrogen storage area.

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

NOTE 2 When hydrogen is delivered in transportable cylinders, tube trailers or MEGCs, safety relief devices within the cylinder/group of vessels are not always included.

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.

7.3.3 Gaseous hydrogen storage siting recommendations

7.3.3.1 Ground storage

When stored above ground, gaseous hydrogen buffer storage vessels or assemblies shall be situated in the open air or a suitable enclosure or building (see [5.3.6.3](#)).

The foundation for a gaseous hydrogen storage vessel shall be appropriate to accommodate the weight of the equipment placed on it and shall be made of concrete or any other suitable non-combustible material. Foundations for gaseous hydrogen storage vessels should be designed and constructed to prevent frost heaving where applicable. In addition, if onsite hydro-testing is anticipated, then the foundation shall be designed to withstand the weight of the vessel when filled with water.

7.3.3.2 Buried underground storage

Buried hydrogen storage vessels shall be adequately protected against corrosion.

Buried process connections shall be installed in accordance with [7.2](#).

The design and installation of the buried hydrogen storage shall take into account requirements for maintenance and inspection (see [14.9](#)).

7.3.3.3 Below ground vaults

It is presupposed that below-ground vaults constructed on-site are 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 vessels 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 vessels.

Ventilation or other measures shall be provided to prevent accumulation of leaked hydrogen gas.

Ingress of water shall be prevented, or a drainage system to manage water ingress shall be provided. If installed at grade and subject to vehicle loading, the top shall 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 shall be sufficient clearance between the gaseous hydrogen buffer storage vessels and the vault to allow for inspection and maintenance of the vessels 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 shall be vented to an appropriate location as specified in [5.3.3](#).

At each entry point to a vault, a warning sign indicating the procedures for proper entry into confined spaces shall be posted. Entry points should be secured against unauthorized entry and vandalism.

7.3.3.4 Roof top or canopy installation of gaseous hydrogen systems

7.3.3.4.1 General

Where hydrogen generators, compressors, gaseous buffer storage vessels, piping systems and their related accessories are located on building or canopy roofs, the installation should meet the recommendations of [7.3.3.4](#).

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 shall 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.

7.3.3.4.2 Roof structural recommendations

It is presupposed that the roof structure supporting the hydrogen equipment and vessels is 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.

7.3.3.4.3 Gaseous hydrogen storage mounting

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

The vessel mounting structure shall be securely affixed to the roof.

7.3.3.4.4 Other hydrogen equipment mounting

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

7.3.3.4.5 Fire protection

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

- measures shall be provided to avoid overpressure/rupture 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 shall have a minimum fire-resistant rating, not less than that required by the type of construction for the building.

7.4 Hazardous areas (with potentially flammable mixtures)

7.4.1 General

Hazardous areas shall be identified and classified according to IEC 60079-10-1 or other regionally accepted methodologies.

Hazardous areas are applicable from points of potential releases of hydrogen and/or other flammable fluids including possibly flammable mixtures in ventilation exhausts from enclosures or building with hydrogen or processing equipment.

See [5.3.2](#) for identifying issues associated with the potential formation of hydrogen and/or other flammable mixtures and approaches to minimise the hazard.

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 may be treated as an outdoor area (i.e. "medium" degree and "good" availability). If the canopy is within the height of the hazardous area, the hazardous area should extend to the border of the canopy. See [5.3.4](#) for mitigating hazards due to the formation of flammable mixtures under canopies.

Where enclosures are placed around hydrogen equipment to contain and/or control hazardous areas, these should be in accordance with [5.3.6.3](#) and [7.11](#). The potential release of flammable fluids from either the natural or active ventilation exhausts from enclosures should be considered in the risk assessment and, if appropriate, in the classification of hazardous areas. Locations below the ventilation exhausts from enclosures may be excluded from consideration. Means to limit the quantity of hydrogen that could be released within the enclosure should be considered, for example, by the use of automatic isolation valves in the hydrogen supply to the enclosure.

The potential for flammable gases leaking from one compartment within an enclosure to another adjacent compartment (of the enclosure) shall be considered in the risk assessment and, if appropriate, in the classification of hazardous areas (see [7.11.4](#)).

Area classification around venting system outlets should be defined on the basis of a foreseeable flow rate, under normal operating conditions, but also considering reasonable potential upset or fault conditions as defined in [7.8.3](#), with the exception of fire conditions and voluntary, manually initiated response to emergency conditions.

7.4.2 Equipment in hazardous areas

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.

See [10.2](#) for bonding and grounding of equipment, the selection and installation of electrical equipment, and the protection of ignition flammables from static discharge.

In addition to the electrical ignition sources, mechanical equipment can also ignite hydrogen and other flammable fluids. Examples of such ignition sources are as follows:

- sparks from rotating fan blades; or
- hot surfaces.

Mechanical equipment and mechanical parts of electrical equipment installed in hazardous areas shall be protected in accordance with the ISO/IEC 80079 series if such parts are not protected according to the requirements in the IEC 60079 series.

NOTE As an example, it is sufficient that an explosion protected electrical fan complies with the requirements for electrical machines according to IEC 60079-0.

7.5 Hydrogen compressors

7.5.1 General

Each compressor shall be equipped with pressure relief device(s), or equivalent safety-instrumented systems to prevent overpressure.

All equipment shall comply with [7.4.2](#).

Compressor enclosures shall comply with [5.3.2.3](#) and [5.3.6.3](#).

The compressor and ancillary systems, where applicable, shall be consistent with use in the piping system described in [7.2](#). Sufficient compensation for potential vibration or movement of the compressor should be provided such that piping systems are not damaged and that leaks do not occur.

Compressors should be designed with particular reference to hydrogen service and to minimise the introduction of contaminants. The ingress of air at the inlet to the compressor shall be avoided at all times to prevent the formation of flammable mixtures.

Risks associated with installation, maintenance, and operation of compressors shall be assessed, and countermeasures shall be defined and implemented to protect equipment and prevent potentially hazardous events from occurring. 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 to purge the compressor(s) with inert gas prior to maintenance operations shall be provided, including a written procedure, to enable effective inerting.

7.5.2 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 shall not be transferred to the piping work.

7.5.3 Control and monitoring

7.5.3.1 General

Safety controls shall be installed to ensure temperature and pressure levels do not exceed or fall below set operating levels, for instance for inlet pressure, discharge temperature and pressure, with the control system instigating an alarm and/or shutdown as appropriate, or appropriate alternate measures.

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

7.5.3.2 Inlet pressure

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

For example, the inlet pressure should be monitored by a pressure indicator/switch, with the control system instigating an alarm and/or shutdown as appropriate, 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 due to a low inlet pressure, 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.

7.5.3.3 Discharge temperature

The temperature after the final stage of compression, or the temperature after the cooler, where fitted, shall be monitored by a temperature indicator/switch with the control system instigating an alarm and/or shutdown as appropriate at a predetermined maximum temperature.

7.5.3.4 Discharge pressure

The pressure after the final stage of compression shall be monitored by an indicator/switch with the control system instigating an alarm and/or shutdown as appropriate, or initiate alternative actions, such as recycling, at a predetermined maximum pressure which is below that of the over-pressure protection.

7.5.3.5 Cooling water alarm

The cooling water system should be monitored by an indicator/switch, with the control system instigating an alarm and/or shutdown as appropriate in case of low pressure, flow or high temperature.

7.5.3.6 Purge gas/pressurisation protection of electrical equipment

Where the motor and auxiliary equipment are purged by an inert gas, or protected by pressurisation with compressed air or an inert gas, low pressure/flow shall be indicated by an alarm, which shall be arranged to shut down the motor and auxiliaries as required by IEC 60079-2.

7.5.3.7 Purge gas/pressurisation protection of crankcases

Where the compressor crankcase is purged by an inert gas, or protected by pressurisation with compressed air or an inert gas, low pressure/flow shall be indicated by an alarm, which shall be arranged to shut down the compressor.

7.6 Instruments for gaseous hydrogen systems

Instruments shall be rated for service in the hydrogen system. The pressure and temperature ratings of the instrument casing shall comply with the requirements of the piping system (as defined in [7.2](#)).

Instruments dedicated for various functions on the fuelling station should be verified for their intended purpose.

Instruments and gauges shall be designed and located such that, in the event of a leakage or rupture, and possible subsequent fire, the risk to personnel is minimised. Examples are the use of snubbers, safety "glass" and blowout backs on pressure gauges.

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

The installation and use of instruments shall be consistent with the electrical area classification and shall, when applicable, comply with applicable provisions of the IEC 60079 series.

7.7 Filters for gaseous hydrogen

The rating of pressure-bearing housings in gaseous hydrogen systems of the fuelling station shall be consistent with its use in the piping system (as defined in [7.2](#)).

Filters and separators shall be sized for the maximum hydrogen gas flow and for the expected impurities in the hydrogen gas (see [Clause 9](#)), and, where appropriate, should be provided with sufficiently large sumps or collecting tanks. If 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 shall 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 shall 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 shall 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, shall be provided.

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

7.8 Gaseous hydrogen vent systems

7.8.1 General

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

The requirements of [7.1](#) and [7.2](#) shall be applied to pressure-bearing piping of the vent system.

The vent discharge piping system shall be designed to not rupture in the event of ignition of a flammable hydrogen air mixture in the system.

The vent system shall be designed for the thrust of the discharging jet. The reaction of this thrust on the PRD nozzle forces and moments shall also be addressed to ensure that the PRD is properly supported and that the integrity of the high pressure piping system and the vent pipe are maintained.

Vent stacks shall be bonded and grounded according to [10.1.3](#). Vent stacks should be designed to be able to carry lightning currents without adverse effects, unless otherwise protected (see [10.1.4](#)).

Hydrogen vent piping and associated valves/devices/systems shall be electrically grounded and bonded as required by IEC 60204-1 to give protection against the hazards of the development of electrical charges, stray electrical currents, static electricity and lightning.

Hydrogen venting systems shall be designed and sized according to [7.8.2](#) through [7.8.4](#).

Vents from high pressure systems may be connected as long as properly sized per [7.8.2](#) with consideration of possible flow from more than one source.

NOTE 1 For the venting of hydrogen from liquid hydrogen systems, see [6.2.2.10](#).

The position of hydrogen vent stacks shall be taken into account in the layout of the installation and shall be such that the vent may be used for operation, maintenance and to allow depressurisation in emergency situations [for example, when there is a fire in the vicinity (see [5.3.6.4](#))] without creating hazardous conditions. Consideration shall 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 shall be arranged to discharge to open air, and so as not to generate a hazard for persons, neighbouring structures, or personnel areas, and should consider safety distances to electrical lines and other ignition sources, air intakes, and building openings. The vent stack shall not discharge where accumulation of hydrogen can occur, such as below the eaves of buildings.

Hydrogen dispersion and radiated heat calculations shall be carried out to establish the location and height of vent stack exits. Further detail is provided in [5.4.2](#).

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

NOTE 2 Flame arrestors are typically used on combustion systems such as a pre-mixed air fuel supply to a hand torch. 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.

NOTE 3 EIGA document 211/17 and CGA G-5.5 provide further guidance.

7.8.2 Vent outlet

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

Vent stacks shall be designed to avoid the collection of water (ice) and organic debris which may impede or impair the venting process.