Hydrogen Refuelling Stations

Overview

As we transition to Net Zero, hydrogen is expected to play a key role in decarbonising transport, in particular the heavy-duty segment. A network of hydrogen refuellers will be needed to accommodate this shift and provide drivers, fleet operators and vehicle manufacturers with the confidence to build and operate these new vehicles.

A hydrogen refueller generally consists of two areas that are physically separated: the plant area and the refueller forecourt, as shown in the process diagram on page 2. The plant area contains equipment for hydrogen supply and/or production, compression, storage and chilling.

The plant area is physically separated from the forecourt and access is restricted by either fencing or a wall with locked gates, to prevent unauthorised access.

The forecourt is the customer facing area of the hydrogen refuelling station and has general access. Sufficient separation distance must exist between any hydrogen production and storage equipment and the forecourt for safety reasons. A blast wall can be used to limit physical distance.

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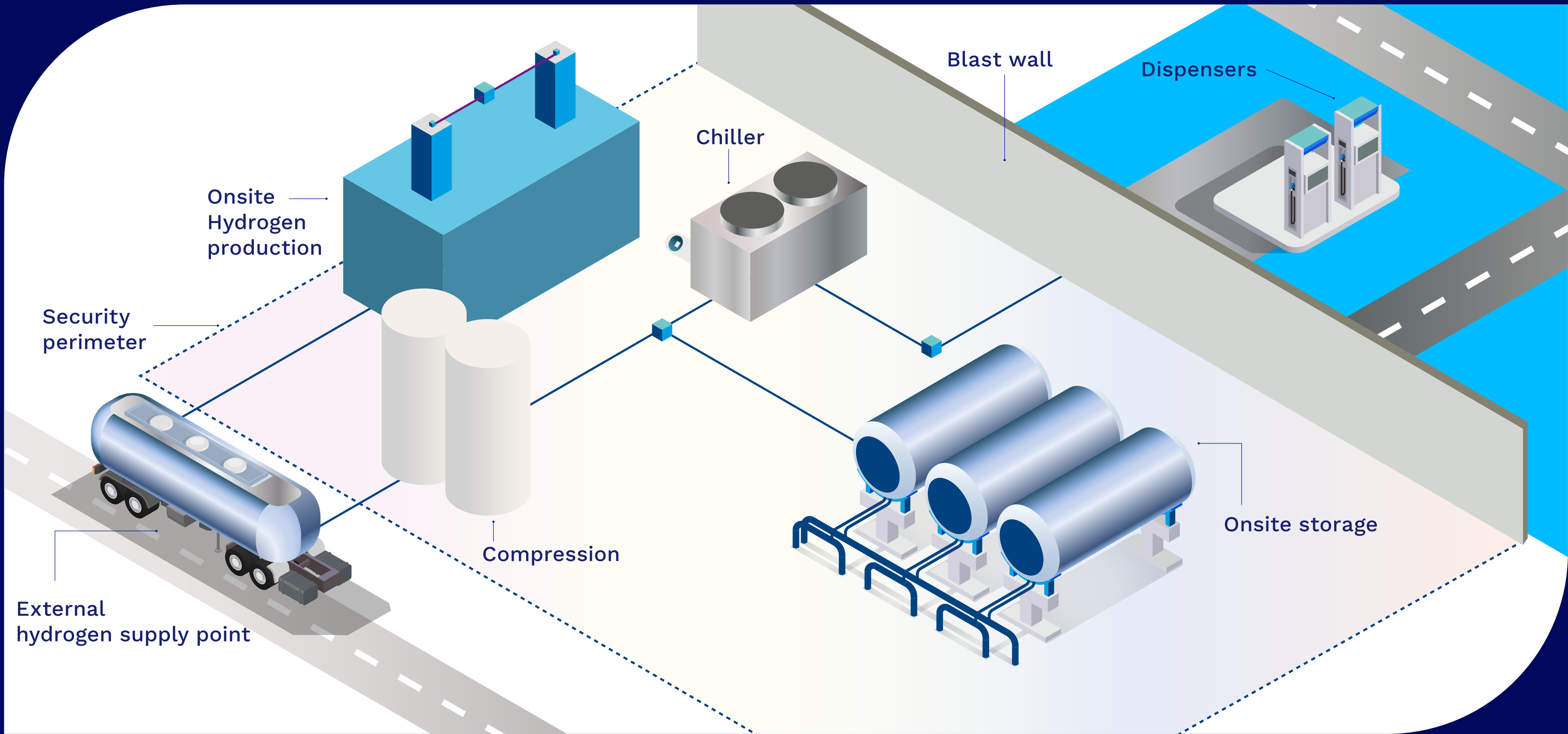
Hydrogen refuelling station – process overview



Hydrogen Supply

Hydrogen for the refueller can be supplied in a number of different ways, including onsite production, or deliveries by tube trailer or pipeline.

Onsite production
Some refuellers may have onsite production of hydrogen for example through electrolysis, using water and electricity as feedstock. Determining whether onsite production is appropriate is mainly an economical choice which depends on many factors, including access to cheap and renewable (or low carbon) electricity, access to a sustainable source of water, and scale of production/offtake. Currently, refuellers are typically designed to serve fleets of vehicles with an aggregated demand of several hundreds to c. 1,000 kg per day, ideally in a modular fashion to allow for a degree of expansion. Fleets routinely consist of tens of heavy duty Fuel Cell Electric vehicles, such as buses or refuse collection vehicles (RCV). Other vehicles, such as light duty fuel cell electric cars or dual fuel HDV can add critical demand to aid refueller economics. This type of scale would generally require an installed electrolyser capacity of 1 – 4 MW. Methods of hydrogen production including electrolysis are covered in other fact sheets. Electrolysers should be housed within weatherproof enclosures to protect the equipment from the elements. Depending on size, shipping containers can be used for this.

External supply
Hydrogen refuelling stations are generally set up to accept fuel deliveries from an external source regardless whether there is onsite production or not. This either provides an alternative to onsite production, or additional security of supply during planned/unplanned electrolyser maintenance activities.

Hydrogen tube trailers (see the Compression, Storage & Distribution of Gaseous Hydrogen fact sheet) can deliver several hundreds of kg of hydrogen at a time. They will connect their onboard storage tanks to a gas interface panel, that allows safe and efficient transfer of hydrogen gas to the refueller's onsite storage tanks, often via the onsite compressor to enable onsite storage at the correct pressure for dispensing.

If tube trailers are the main source of hydrogen, daily deliveries are currently standard practice, due to the significant cost of installing large amounts of onsite storage. Fuel delivery frequencies for conventional fuel stations are usually somewhat lower, due to the lower cost of onsite storage, although fuel stations with high demand can have deliveries every 1 – 2 days. Depending on the scale of the refueller and proximity to a hydrogen production site, a dedicated pipeline may also supply the facility (pipelines are also covered in the Compression, Storage & Distribution of Gaseous Hydrogen fact sheet).

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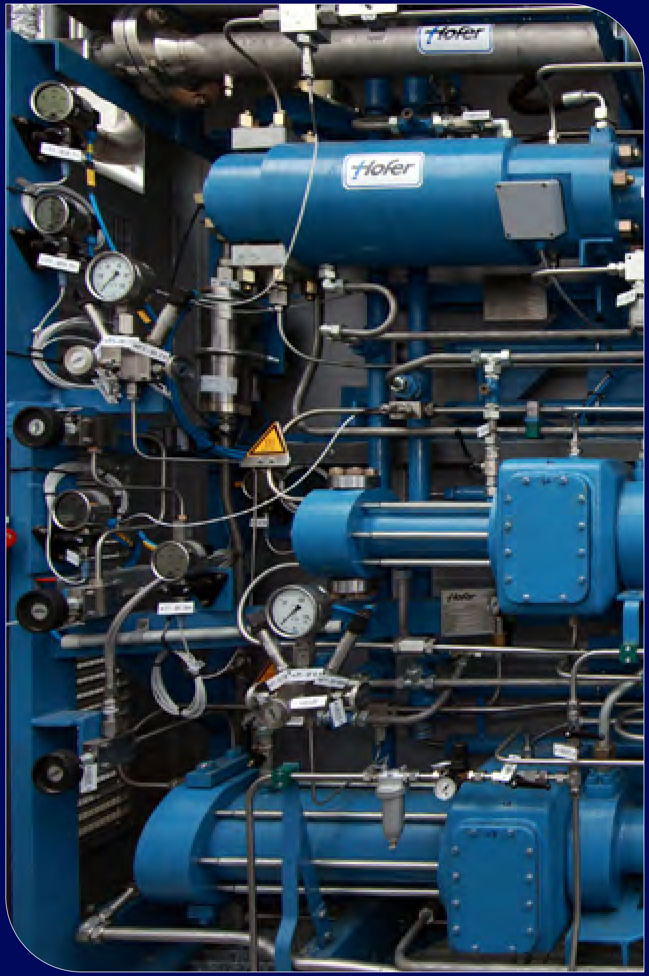
Hydrogen Compression

Onsite storage of hydrogen is commonly done through compression and subsequent transfer to specialist storage tanks. Due to hydrogen's low gravimetric density, efficient storage requires high pressures, which is particularly important for onboard vehicular applications where space is limited. In order to refuel vehicles at their onboard storage pressure, onsite stationary storage is also performed at high pressures. Compressors take the hydrogen from the supply point as input and compress it to typical pressures of 500 – 1,000 bar. Compressors are usually contained within weatherproof enclosures, such as shipping containers. They can be mounted on steel skids for ease of installation and transport.

Compressor technologies
The compression technology of choice is highly use-case dependent and for hydrogen refuellers the requirements are high purity hydrogen at very high pressures, up to 1,000 bar. Compressor operation is also intermittent, due to uneven demand throughout the day. This combination of requirements means that the most common forms of compressors in a hydrogen refueller are either diaphragm, hydraulic or ionic compressors (detailed in the Compression, Storage & Distribution of Gaseous Hydrogen fact sheet).

It is likely that multiple compression stages are needed to achieve the pressures required, due to limitations in compression ratio of a single cycle. The number of compression stages is highly dependent on the choice of hydrogen supply. For instance, an electrolyser will produce hydrogen typically at 30 bar, whereas piped hydrogen is likely delivered up to c. 100 bar, requiring somewhat less compression or fewer stages. Tube trailers store and deliver hydrogen at higher pressures still, several hundreds of bar, although this delivery pressure will continually decrease as hydrogen is transferred from tube trailer to onsite storage, thus requiring more compression as the transfer nears completion.



Onsite Hydrogen Storage

Hydrogen storage tanks provide high pressure buffer storage which helps meet demands from the refuelling forecourt. Hydrogen is usually stored at pressures between 500 and 1,000 bar for refuelling at 350 and 700 bar, respectively. Onboard storage for heavy duty vehicles is typically at 350 bar, whereas light duty and passenger vehicles store hydrogen at 700 bar. High pressures are required to store sufficient amounts of hydrogen fuel, due to its low gravimetric density.

Onsite storage tanks usually come as banks of cylinders which are manifolded but can hold hydrogen at different pressures. Different tank technologies exist, classified as Type I,II, III, IV and so on. These are detailed in the Compression, Storage & Distribution of Gaseous Hydrogen fact sheet. The different types describe different materials and different architectures (such as layering) and are suitable for different hydrogen pressures, with Type III and IV most commonly used in refueller settings thanks to their suitability for high pressures. The manifolding is by stainless steel pipework, valves and fittings which are suitable for high pressure operation.

The tanks are manifolded but will have separate pressure gauges or transducers and valves so that they can hold varying hydrogen pressures. The pressure inside the cylinders can be monitored by a control system through these transducers and the control system can increase or decrease the hydrogen production (e.g. electrolyser) and compression rate when required.

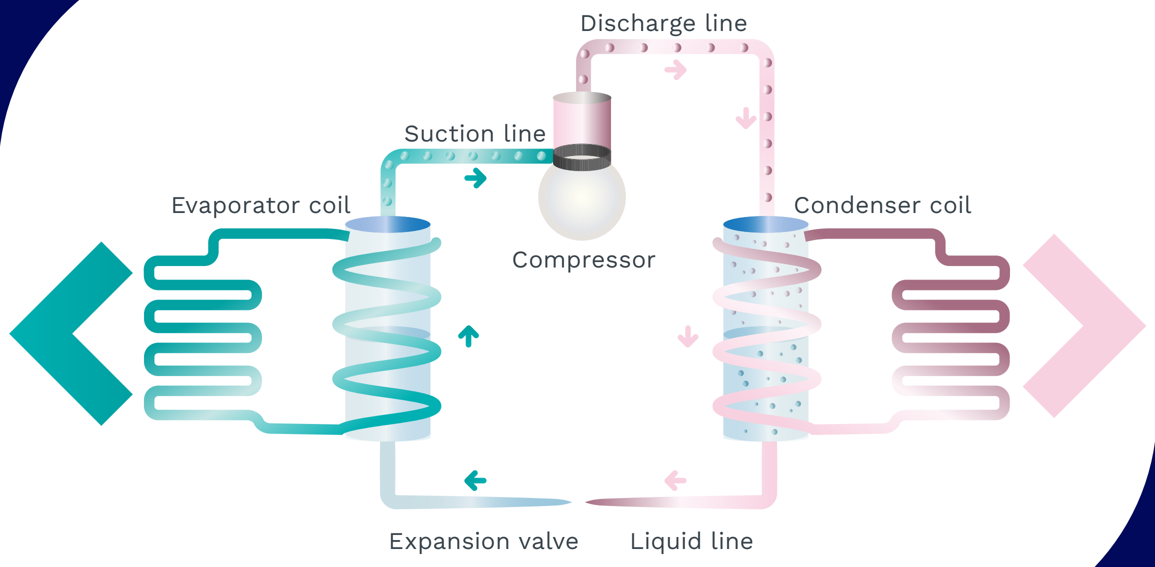
The amount of onsite hydrogen storage that is required is dependent on a number of factors. Daily refuelling demand is of course a critical factor, but so are refuelling windows, choice of hydrogen supply, frequency of supply in case of tube trailer deliveries and general redundancy considerations. Refuelling fleets of buses and/or RCVs can often be time constrained, depending on operational requirements, putting increased requirements on the amount of high pressure storage. In view of the above consideration, a typical storage quantity would be 1.5 - 2x the daily demand

Hydrogen Chillers

Chillers are essential for safe hydrogen refuelling at high pressures and at high filling rates. Although not strictly necessary, high filling rates are desirable from an operational point of view, providing the customer with a refuelling experience that is similar to filling up with conventional fuel, such as diesel or petrol. Whereas most gases cool on expansion from a pressurised source, hydrogen heats up during this process. At high pressures and high flow rates, this heating effect can cause damage to the vehicle's onboard storage tanks, and this must be prevented by pre-cooling the hydrogen before it enters the vehicle. Chilling can be performed down to c. –40°C. The chillers are positioned in between the storage tanks and the hydrogen dispensing equipment and thus cool the hydrogen gas in flow. In some cases, the chiller is integrated with the dispenser and thus comes as a single unit.

Chillers use conventional cooling technology, utilising compression, expansion of a suitable refrigerant and heat exchange to ambient to achieve rapid cooling of the flowing hydrogen gas down to –40°C, prior to entering the dispensing unit.

Refrigerant is contained within a closed circuit and exchanges heat both with hydrogen and ambient.



Dispensing & Metering

Hydrogen dispensing occurs in the forecourt of the hydrogen refuelling station. It should provide a user-friendly interface, not requiring specialist training to operate, much like operating a diesel or petrol dispenser in a typical fuel station forecourt.

There are currently two standard vehicle onboard hydrogen storage pressures, 350 bar and 700 bar for heavy duty and light duty vehicles, respectively. This is not dissimilar from conventional fuel stations being able to dispense different fuels, such as diesel and petrol with varying grades. Although heavy duty vehicles may also store hydrogen at 700 bar in the future, the two storage pressures are likely to co-exist for some time. Therefore, being able to dispense at two different pressures allows maximum flexibility in the type of vehicle a refueller can serve. However, this adds complexity and capital cost to the overall refueller setup. Different dispensing nozzles allow dispensing at different hydrogen pressures. Accidental dispensing at the wrong pressure is prevented by non-compatible fuelling ports on the vehicles. Dual dispensers are available, which can dispense at both pressures. The ability to dispense at 700 bar also requires storing hydrogen at higher pressures (900 – 1,000 bar), which adds further significant cost to the overall refueller.

Dispensing is typically done through a so-called cascade filling protocol, whereby hydrogen fuel flows from the multiple onsite hydrogen storage tanks, directly into the vehicle's onboard storage tanks (via chiller and dispenser), without the need for additional compression. An automated control system typically allows switching the flow between different onsite storage tanks, optimising their individual pressures and allowing for efficient refilling.

A Compressed Natural Gas (CNG) style locking mechanism at the nozzle ensures a gastight fitting with the vehicle fuelling port. The dispenser will run a number of diagnostic checks, such as the vehicle's onboard storage tank's hydrogen pressure and leak tightness before commencing hydrogen flow. The flow automatically stops when the vehicle's onboard tank has been filled, or the process can be stopped manually by the operator/customer.

Accurate hydrogen metering during dispensing is a critical requirement for hydrogen refuelling applications, ensuring correct billing of HRS users, similar to petrol and diesel refuelling. Meters must manage wide pressure and temperature ranges and accommodate transient flow. Currently, Coriolis meters are the meter technology of choice for all hydrogen refuelling due to their adaptability.

Fuelling protocols, such as SAE J2601, are used to monitor pressure, fuel flow and the vehicle's tank temperature, to allow safe refuelling. These protocols continue to be reviewed and optimised to enable fast and efficient refilling, which is of particular importance for heavy duty vehicles.

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General hydrogen safety considerations

Equipment in containers / enclosures

To prevent the build-up of flammable gas mixtures inside enclosures (e.g. electrolyser or compressor containers), these need to be equipped with a ventilation system that effects a number of air changes per hour. They should be equipped with hydrogen detector(s) which is/are interfaced with the relevant control system, so that in the event of a detection above a threshold concentration (typically 1 vol% hydrogen in air) the system shuts down to prevent further build-up of hydrogen. A detection may also trigger an increased rate of ventilation to purge the enclosure and reduce the hydrogen concentration. Passive ventilation can also be an effective means of reducing the probability of flammable mixtures forming. Any electrical equipment inside containers must be ATEX rated to remove any sources of ignition.

Pressure monitoring

Refueller pipework and any interfaces for external supplies must be fitted with pressure monitoring equipment and solenoid shut off valves, so that in the case of a catastrophic leak, for instance from a pipe rupture or burst fitting, valves are closed upstream to interrupt the supply and stop continued hydrogen leakage.

Hydrogen bulk storage

Bulk storage of hydrogen, or any flammable gas for that matter, is normally placed outside, providing natural ventilation and thus preventing the build-up of explosive mixtures, due to accidental hydrogen releases, for instance through leakages. A canopy over the storage tanks is however acceptable and will minimise damage through weathering. Any released hydrogen will however accumulate at high level, due to the gas's low density, and this should be considered in designing and installing a canopy

Hydrogen purity

Hydrogen purity is not only essential for fuel cell electric vehicles, it is also critical for safety purposes. Oxygen in particular must remain within acceptable levels to prevent explosive mixtures forming. Oxygen can slowly build up over time, due to air leaks and during making and breaking of gas connections (e.g. external supply transfer, dispensing). Oxygen monitoring is recommended practice.

Hydrogen supply componentry

Component	Material(s)	Specifications
Quick release couplers or similar for external supply interfacing	Stainless steel, suitable for hydrogen operation	SS 300 series, typically AISI 316L or 304L
Various type valves, incl. ball valves, non-return and actuated shut off valves.	Stainless steel, suitable for hydrogen operation	SS 300 series, typically AISI 316L or 304L
Flexible tubes, e.g. braided SS for hydrogen transfer from tube trailer	Stainless steel, suitable for hydrogen operation	SS 300 series, e.g. AISI 316L or 304L
Vacuum systems and inert gas (e.g. nitrogen) for purging lines		
Pressure relief devices and venting stacks	Stainless steel, suitable for hydrogen operation	SS 300 series, e.g. AISI 316L or 304L
Support structures for pipework, e.g. overhead gantries, bracketing and foundations	Material suitable under service conditions, e.g. combination of concrete, steel, synthetic rubbers/polymers	Various standards, e.g. ASME B31.3
Earthing and bonding	Various, incl. copper and aluminium. Compatibility and suitability must be checked, see BS 7430	BS 7430

Onsite hydrogen storage

Component	Material(s)	Specifications
High pressure hydrogen storage tanks	See: Compression, storage and distribution of gaseous hydrogen fact sheet	See: Compression, storage and distribution of gaseous hydrogen fact sheet
Cylinder banks	Steel frame on concrete base. Restraining system to hold cylinders in place, e.g. straps, allowing for contraction/expansion	Frame – Carbon or stainless steel
Oxygen monitoring in tanks		
Open enclosure with slanting canopy/roof protecting cylinders and componentry from weather, whilst allowing ample natural ventilation to prevent build up of hydrogen at high levels	Typical construction materials, e.g. steel and concrete	Design guidelines – see e.g. BCGA CP33 and CP44

Chillers

Component	Material(s)	Specifications
Refrigerant suitable for cooling to −40°C	Various, e.g. R290 and R717 (ammonia and propane)	
Heat exchangers, e.g. plate exchangers, including fans, and optionally secondary cooling fluids	Heat exchanger – Aluminium or stainless steel	
Compressors and expansion vessels	Secondary cooling fluid – typically glycol/water based	
Refrigerant pumps	Typically stainless steel, suitable for refrigerant	
Temperature monitoring and control		
Pressure monitoring and control		

Dispensers and metering

Component	Material(s)	Specifications
Dispenser housing		
Pressure regulators and monitoring (gauges / transducers)		
Vacuum pumps or system for purging dead volumes		
Anti whipping fuelling hoses suitable for hydrogen	Braided stainless steel, synthetic rubber or polymer sheath	
Hydrogen meters		Coriolis based technology – ISO 10790:2015 Ultrasound based technology – ISO 17089-1:2019 Hydrogen metering – OIML R 139
Nozzles		ISO 17268:2020 SAE J2600
Vehicle to dispenser comms and control system		SAE J2601 SAE J2799
Canopy – suitably shaped to prevent hydrogen build up at high level	Construction materials	Design guidelines – see e.g. BCGA CP33 and CP44
Features protecting equipment from vehicle impact, e.g. crash barriers		
Earthing and bonding		BS 7430
Breakaway couplers incl. automatic safety valves		
Emergency stop buttons		
Internal hydrogen detection		

General componentry

Component	Material(s)	Specifications
High pressure pipework, manifolding and fittings	Stainless steel, suitable for hydrogen operation	SS 300 series, typically AISI 316L or 304L
Pressure gauges, transducers and control system		Suitable for high pressure and hydrogen service. Stainless steel connections (e.g. AISI 316)
Temperature monitoring/sensing and control system		
Shipping containers, incl. acoustic shielding.	Containers – carbon steel Acoustic shielding – proprietary	Various depending on requirements, e.g. 20ft or 40ft
Coatings for containers	Suitable for service conditions	Typically C2
Ventilation systems (passive and active), including fans, louvres, air filters, etc. – linked to gas detection		
Gas detection		Various technologies, suitable for hydrogen detection, incl. •Electrochemical and catalytic bead (point detection) •Ultrasonic/acoustic •Thermal conductivity based (handheld) •UV and IR for flame detection
Process control system – monitoring pressures, temperatures and controlling rates of tank filling/emptying, compression, etc.		
Foundations for containers, dispensers, hydrogen storage cylinder banks, etc.	Concrete	

Standards

Standard	Description	Body
ASME B31.3	Process Piping – ASME code for pressure piping	American Society of Mechanical Engineers
ISO 19880-1:2020 Also ISO 19880-xx xx: 2 – 10	Gaseous hydrogen – Fuelling Stations Part 1: minimum design, installation, commissioning, operation, inspection and maintenance requirements	International Organisation of Standardisation
ISO 14687-2	Hydrogen fuel quality — Product specification	International Organisation of Standardisation
ISO 17268:2020	Gaseous hydrogen land vehicle refuelling connection devices	International Organisation of Standardisation
SAE J2600 and 2601	Compressed Hydrogen Surface Vehicle Fueling Connection Devices Fueling Protocols for Light Duty Gaseous Hydrogen Surface Vehicles	SAE International
SAE J2799	Hydrogen Surface Vehicle to Station Communications Hardware and Software	SAE International
OIML R 139	Compressed Gaseous Fuel Measuring Systems for Vehicles	International Organization of Legal Metrology
BS 7430	Code of practice for protective earthing of electrical installations	British Standards
ISO 10790:2015	Measurement of fluid flow in closed conduits — Guidance to the selection, installation and use of Coriolis flowmeters	International Organisation of Standardisation
ISO 17089-1:2019	Measurement of fluid flow in closed conduits — Ultrasonic meters for gas	International Organisation of Standardisation

Regulations and Codes of Practice

Directive	Description	
ATEX Directive, 2014/34/EU	Two EU directives which describe the minimum safety requirements for workplaces and equipment used in explosive atmospheres - ATEX Workplace Directive and the ATEX Equipment Directive	European Commission
Pressure Equipment Directive (PED) – 2014/68/EU	Applies to the design, manufacture and conformity assessment of stationary pressure equipment with a maximum allowable pressure greater than 0.5 bar.	European Commission
Dangerous Substances and Explosive Atmospheres Regulations 2002 (DSEAR)	Requires employers to control the risks to safety from fire, explosions and substances corrosive to metals	Health and Safety Executive

Directive	Description	Organisation
BCGA CP4	Gas supply and distribution systems (excluding acetylene)	British Compressed Gas Association
BCGA CP33	The bulk storage of gaseous hydrogen at users' premises	British Compressed Gas Association
BCGA CP41	The design, construction, maintenance and operation of filling stations dispensing gaseous fuels	British Compressed Gas Association
BCGA CP34	The application of Pressure Equipment (Safety) Regulations to customer sites	British Compressed Gas Association
BCGA CP44	The storage of gas cylinders	British Compressed Gas Association
BCGA GN13	DSEAR risk assessment guidance for compressed gases	British Compressed Gas Association

We would like to thank TÜV SÜD for providing input on hydrogen standards and content on hydrogen metering

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