
Services along the hydrogen value chain

## Storage:

# Pressure vessels

HydroHub

# $H_2$ competence @ HydroHub

Our services run along the entire value chain in the hydrogen industry – from generation through transport and storage to use in various fields of application.

## Energy generation

Renewables (e.g. wind, solar)

Conventional power plants

Geothermal

## $H_2$ generation

Electrolysis

Seawater desalination plants

Reforming processes

Methane pyrolysis

## Distribution/transport

Electrical grid

Pipelines

District heating

Intelligent networks

Refuelling stations/ filling systems

Tankers (lorry, train, ship)

## Storage

Battery storage

Gas tanks

Cavern storage ($H_2$ and $CO_2$)

Pressure vessels

$H_2$ hydride storage

## Consumption/use

Fuel cell system

Methanol synthesis unit

Carbon capture and utilisation

Mobility (e.g. e-fuels)

Reconversion to electricity

Power to gas (gas, heat, liquid)

Industrial applications (e.g. refinery)

# $H_2$ competence @ HydroHub

We give comprehensive support to hydrogen projects and offer a broad spectrum of services in the concept/planning, production, operation and decommissioning/disposal phases.

## Concept/planning

We support you from the start with research and project planning measures and specific tasks. Already at the conception phase, we are there at your side with feasibility studies, strategic and financial consultation and a broad range of organisational and technical services. Alongside concept creation with consideration for legal, technical and economic conditions, we take on the task of analysing the requirements and support you in the process of determining feasibility through basic and design planning all the way to the approval process.

## Production

For over 150 years, it has been one of our tasks to analyse and manage technical sources of risk. With our wide range of specific services, we are thus able to offer you competent help in the integration of hydrogen technologies into the industrial value chain. Our range of services runs from fact-finding and construction through project management, administering documentation and operator's obligations, basic and detailed process engineering all the way to project support through geological, environmental and engineering services during the production process.

## Operation

We support frictionless operation with our extensive range of services and our primary goal of optimising operational reliability and preventing damage. Our services support you in the implementation of your operating strategies and in the accompanying optimisation, maintenance and upkeep concepts. Our safety-oriented process with operational monitoring and the creation of damage-limitation concepts contributes, in the final account, to establishing hydrogen in the popular conception as a safe and controllable technology.

## Decommissioning/disposal

Just as we are there for you in the first concept phase, we are also at your side at the decommissioning phase, providing all the required services for dismantling and disposal – including project management and comprehensive services to handle your operational obligations. We create concepts to the current legal requirements, standards and regulations and support you in identifying, analysing and avoiding the potential risks of your intervention.

# Hydrogen pressure vessels in mobile and stationary use

With the increase in hydrogen applications, the need for storage solutions for mobile application on land and sea has also risen, as has the demand for stationary solutions in the industrial environment, at refuelling stations or in research facilities. Pressure vessels are used for this, vessels which, according to the Operational Safety Directive, require monitoring and thus must be fitted with safety features to protect the container and the operator against potential excess temperatures or pressures.

The current solutions include pressure vessels in metal and composites that store gaseous hydrogen ($CGH_2$) at pressure levels from 20 to 1,000 bar and cryotanks that store cryogenic liquid hydrogen ($LH_2$) in vacuum-insulated containers at relatively low pressures of up to 4 bar. New concepts are assessing the high-pressure storage of cryogenic hydrogen ($CcH_2$). In addition, hydrogen can be stored in solid form – also currently in development are metal hydride storage facilities that can take large quantities of hydrogen at minimal volume and at optimal energy efficiency.

We are your experienced partner in the comprehensive monitoring of production and the evaluation of pressure containers, as well as in the development of prototypes for mobile and stationary applications. With competent experts and the most modern analysis and measurement methods, we supply reliable findings regarding the durability of the materials used, ensure conformity with national and international regulations and support you in benefiting from subsidies. Do get in touch.

# Pressure vessels for gaseous hydrogen ($CGH_2$)

For the storage of gaseous hydrogen, cylindrical vessels of various sizes and materials are used. For stationary use, say, in industrial facilities, large steel tanks that store $CGH_2$ in the low-pressure range (20–200 bar) are deployed. Refuelling stations also have additionally sheathed vessels for higher pressure levels in the mid-range of 450–500 bar and the high-pressure range up to 1,000 bar.

The development of pressure containers to store gaseous hydrogen is constantly progressing. Reasons for this include the requirement to save weight and ensure stability, durability, environmental friendliness and recyclability in the materials used. On the market are four types of pressure vessels, where the pressure tanks of types I, II and III contain metallic components. Starting from type IV, pressure vessels made of fibre-reinforced plastics are asserting themselves as an alternative and are preferred in mobile applications because of their weight advantages. The next generation, type V, will bring yet further weight savings and be made almost completely out of carbon and hybrid fibres.

## Pressure vessel types to store gaseous hydrogen ($CGH_2$)

**Hydrogen vessel type I:**

- walls in chromium molybdenum steel
- typical nominal pressure 200 bar
- use as transport container and for stationary storage

**Hydrogen vessel type II:**

- metallic walls and sheathing of the cylindrical component in glass or carbon fibre
- nominal pressures up to 1,000 bar
- use for stationary storage at hydrogen refuelling stations

**Hydrogen vessel type III:**

- liner of aluminium and complete sheathing in carbon fibre
- typical nominal pressure 350 and 700 bar
- use in fuel cell vehicles and stationary applications

**Hydrogen vessel type IV:**

- liner of plastic and complete sheathing in carbon fibre
- nominal pressure range 350 to 700 bar
- use in fuel cell vehicles and transport containers

**Hydrogen vessel type V (various processes under development, incl.):**

- carbon-fibre composites (CFC materials)
- thermoplastic fibre-reinforced composites (FRCs), carbon neutral
- additional weight saving as against type IV vessels

# Pressure vessels for liquid hydrogen ($LH_2$)

In contrast to the high-pressure storage of gaseous hydrogen, liquid hydrogen is usually stored at low pressure, as a rule between 1.2 and 3.5 bar.

To transform hydrogen into its liquid, cryogenic phase at -253 °C, a lot of energy is required and special cooling technologies must be used. The advantage is the increase in the volumetric energy density and thus the option to transport and store larger quantities of hydrogen in less space. The volume of current cryotanks for stationary storage of $LH_2$ runs from approx. 3,000 to 80,000 litres (thus 2,500 to over 65,000 cubic metres of gas at a pressure of 1 bar).

Cryotanks have an inner and an outer tank made of stainless steel, between which is a high vacuum and multiple layers of insulation. Despite the best possible thermal insulation measures, boil-off losses occur which, depending on the size and fill level of the tank, can amount to 1 to 2 % per day. These arise because of the unavoidable ingress of heat into the interior of the tank, making the operational pressure there of, as a rule, between 1.2 and 3.5 bar, rise to a defined limit. Over a pressure level of around 4 bar, pressure sensors trigger a discharge of gaseous hydrogen, with large-scale stationary tanks able to maintain their cooling for 4 to 5 months without boil-off. To make use of the escaping hydrogen, several cryotanks can be integrated in a surrounding pressure container.

Because of its high energy density, $LH_2$ is suitable for refuelling vehicles that need to travel long distances. For the use of $LH_2$ in lorries and trains, stainless-steel tank systems are being developed, working with operational pressures below 10 bar and further reducing boil-off losses. In comparison to high-pressure vessels, they have marked weight advantages thanks to their lower storage pressure.

# Pressure containers for the transcritical storage of liquid hydrogen ($CcH_2$)

Concepts are being investigated for the compressed storage of cryogenic hydrogen. At very low temperatures of around -220 °C and with very high pressure, up to 1,000 bar, the volumetric density of hydrogen increases once again. The technical requirements of these pressure vessels are correspondingly high, as they must both be able to regulate the temperature like a cryotank and possess the stability of a high-pressure container.

# Gaseous hydrogen in metal hydride storage

Metal hydride storage allows the storage of gaseous hydrogen in minimal space. To this end, metals are used that exothermically bind hydrogen at a chemical level and release it again when heated.

In contrast to storage in high-pressure or cryotanks with the accompanying expenditure on sealing, liquefaction and operational safety, storage in metal hydrides allows an opportunity to use much lower pressure levels while retaining high volumetric energy density.

In research projects like the EU-supported HyCARE Project, prototypes are generated to show the potential of metal hydride storage. Here, the same pressure-resistant shell is used as that for low-pressure gas tanks. To take up 50 kilograms of hydrogen, a tank volume of just 1 to 2 cubic metres is required.

# Our services

From structural and mechanical simulations and calculations of material loads in the design phase to all the required services relating to fire and explosion protection – with comprehensive provision in the fields of consulting, engineering and training, we support you in the following phases of your project:

| | Concept/ Planning | Production | Operation | Decommissioning/ Disposal |
|---|---|---|---|---|
| Computer verification/structural mechanical simulations in plant construction: static and dynamic verifications to national and international regulations, analytical calculations and finite-element simulations (FEM), static/ dynamic load models, mechanical models, calculation of loads (stresses), comparison with material properties for load capacity of the component, evaluation and documentation of the results as a report, damage assessment and analysis | ● | ● | ● | ● |
| Fire protection: Creation of fire safety concepts and assessments, specialist construction management for fire protection, fire risk assessments, fire and explosion cause determinations, risk avoidance plans | ● | ● | ● | ● |
| Explosion protection: determining the safety parameters, explosion and fire protection assessment, explosion and fire protection for machines, for operators, tests on plants requiring monitoring | ● | ● | ● | ● |

## HydroHub

An initiative of TÜV NORD GROUP companies

EE ENERGY ENGINEERS GmbH
TÜV NORD GROUP
Wissenschaftspark
Munscheidstraße 14
45886 Gelsenkirchen

wasserstoff@hydrohub.de
www.hydrohub.de/en

## Your contact

Dr. Carsten Gelhard
Head of the HydroHub
Mobile: +49 (0)160 888-2036
Tel.: +49 (0)201 825-2026
gelhard@energy-engineers.de



HydroHub