Sealing Solutions for Hydrogen

ACCELERATING INNOVATION FOR SUSTAINABLE TECHNOLOGY

TOGETHER WE SHAPE A SUSTAINABLE FUTURE

Transforming to Sustainable Energy

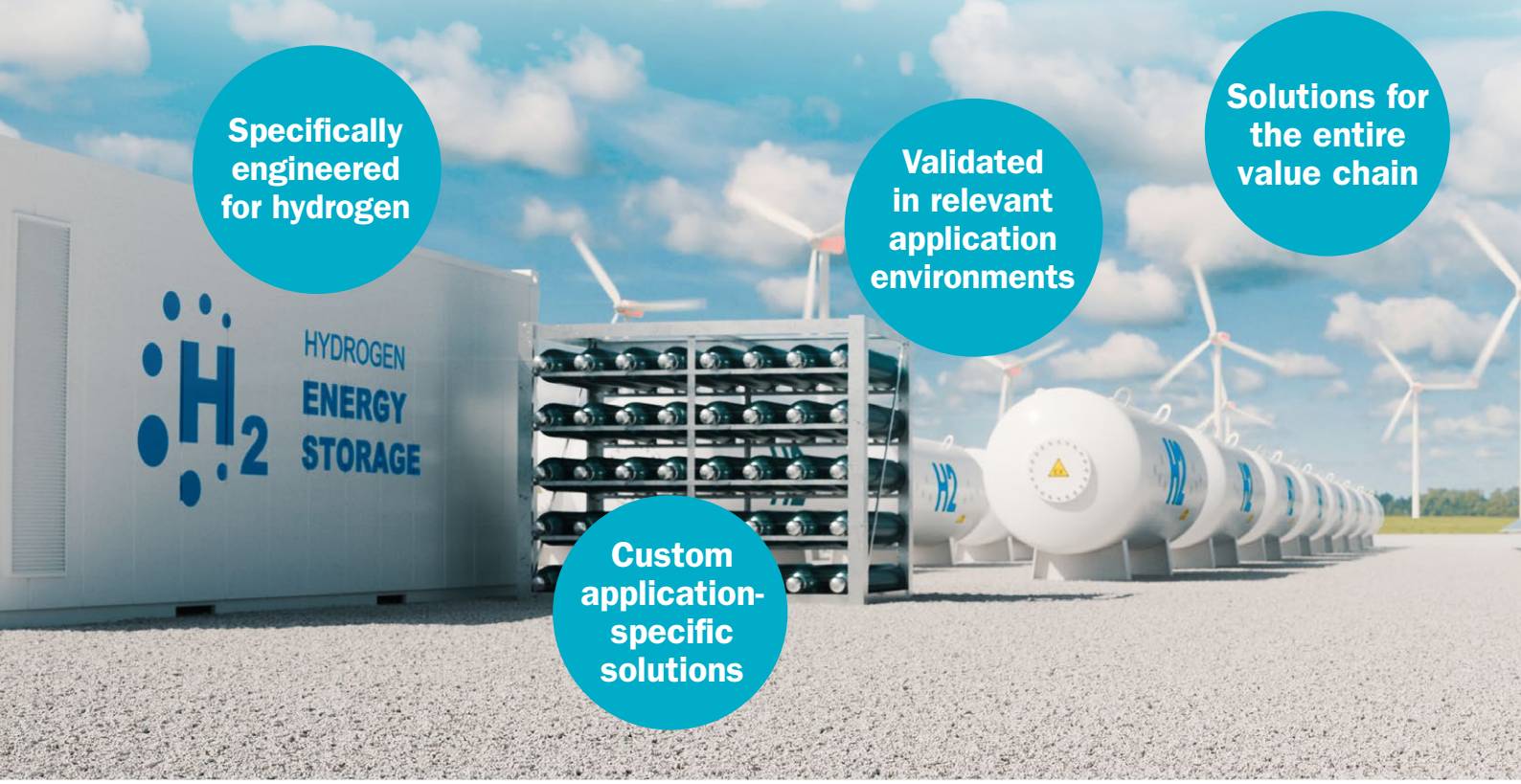
Our H_2Pro™ materials are specially engineered for challenging hydrogen applications across the value chain.

Both as a fuel source and as a storage medium for surplus renewable generation, hydrogen will be a crucial element in the transition to sustainable energy. Predictions envisage €9 trillion in investment pouring into hydrogen, which would make the industry bigger than the oil and gas sector and automobile market combined.

Trelleborg Sealing Solutions is at the forefront of innovation for the entire hydrogen value chain, working with customers to develop proven materials for challenging real-world applications. In the initial absence of recognized sealing standards for hydrogen, our sector-leading R&D has established proprietary testing programs to validate materials for use in hydrogen applications.

Our H_2Pro™ range is a portfolio of specially engineered and validated materials for use with hydrogen, which is difficult to seal due to its challenging chemical characteristics. It includes different compounds of ethylene propylene diene monomer rubbers (EPDM) for a wide variety of conditions, fluorocarbon (FKM) materials for high-temperature applications and silicones offering a wide operating temperature range. It also includes polyurethanes (PU) for extreme durability, thermoplastics such as polyterafluoroethylene (PTFE) and polyetheretherketone (PEEK), which excel in cryogenic and liquid hydrogen sealing, and metals for ultimate static sealing.

Supporting the energy, power generation, off-highway, truck and bus, aerospace, chemical processing and transportation and marine industries, the ever-expanding H_2Pro™ range offers reliable solutions for the wide array of pumps, valves, connectors and numerous other devices across the hydrogen supply chain.



OUR GLOBAL NETWORK

Trelleborg has a global network of facilities developing, testing and producing hydrogen sealing materials to serve customers worldwide, including:

Malta: EPDM and FKM development and molding facility

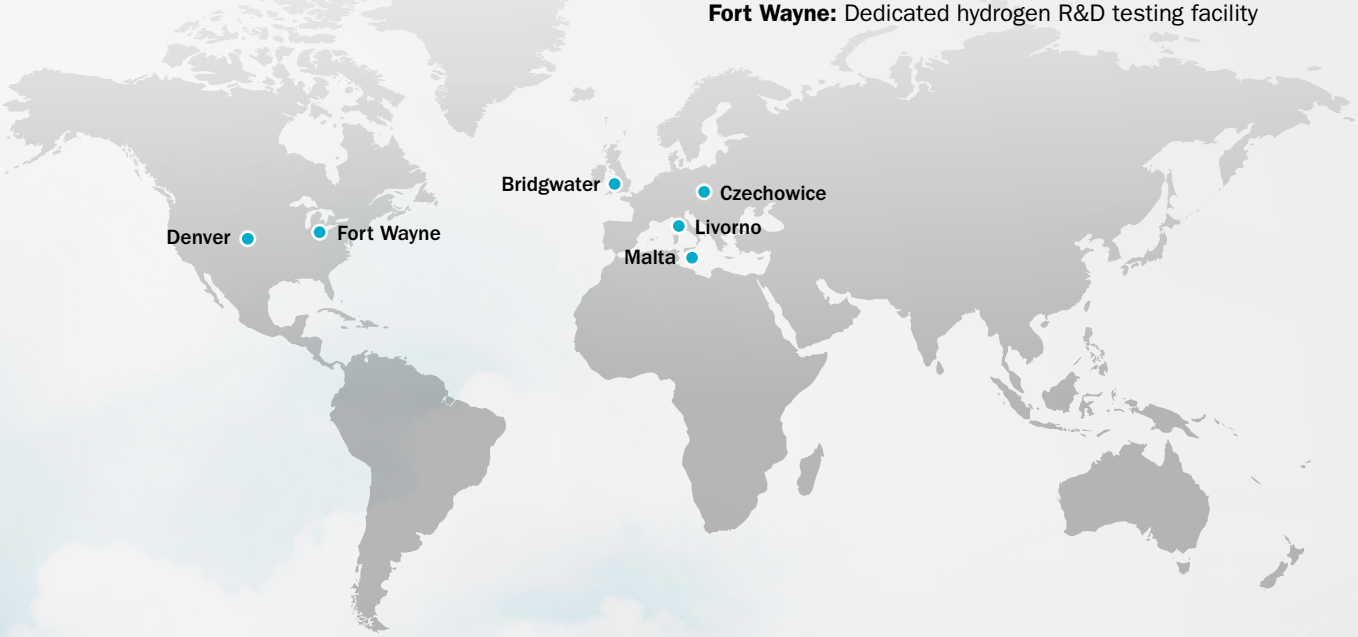
Livorno: PU development and manufacturing facility

Czechowice: Specialist rubber-to-metal and rubber-to-plastic molding facility

Bridgwater: PTFE and metal seal ring manufacture and high-pressure and low-temperature testing facility

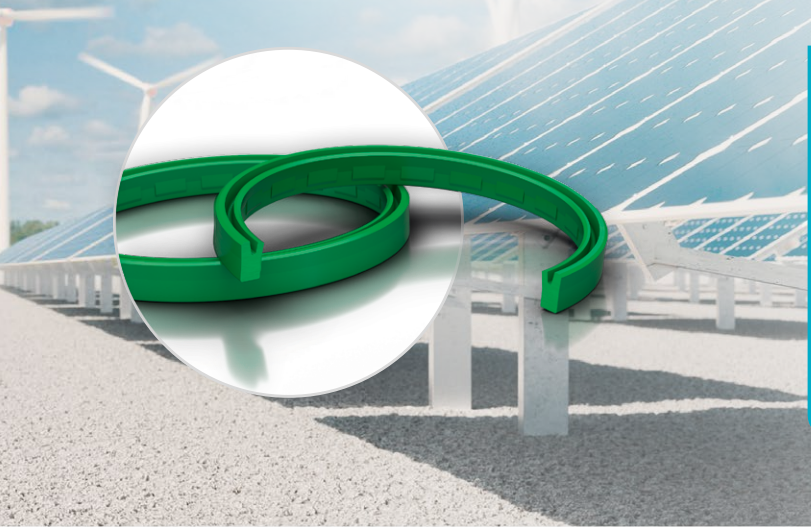
Denver: High Performance Thermoplastics Technology and Development Center and PTFE manufacturing

Fort Wayne: Dedicated hydrogen R&D testing facility



KEY FEATURES AND BENEFITS

- Specifically engineered to meet sealing requirements across the hydrogen value chain
- Fully validated under our proprietary testing programs
- Proven to withstand challenging application environments including resistance to leakage and permeation, high pressures and extreme temperatures, and rapid gas decompression
- Excellent application-specific wear and extrusion properties, extending service life while reducing maintenance time and total cost of ownership
- Trelleborg engineering expertise supports the development of custom solutions



CONTACT YOUR CUSTOMER SOLUTION CENTER

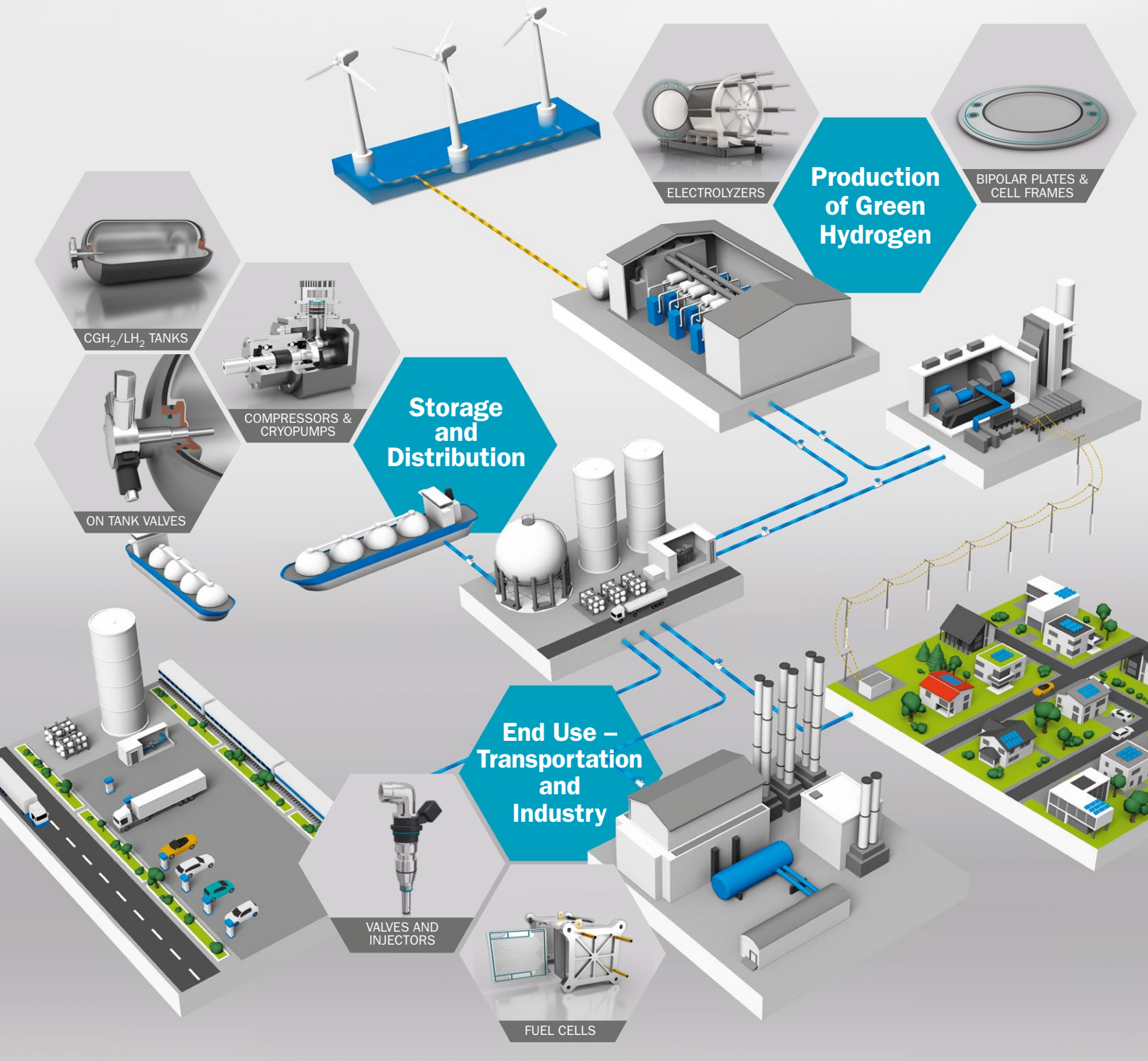
Does your application have unique requirements? Is the operating environment of your application especially challenging?

Reach out to your local Trelleborg Sealing Solutions Customer Solution Center for support.

www.trelleborg.com/en/seals/contact-form

Solutions for the Entire Value Chain

The H_2Pro™ range includes solutions for all stages in the hydrogen value chain.



KEY HYDROGEN VALUE CHAIN CONDITIONS

Compression CGH_2

-20 °C to +170 °C/-4 °F to +338 °F
0 MPa to 100 MPa/0 psi to 14,504 psi

Applications
Diaphragm compressor, ionic compressor, dry running reciprocating piston compressor (hydraulic drive, pneumatic drive or crankshaft) with highly dynamic piston and rod sealing systems

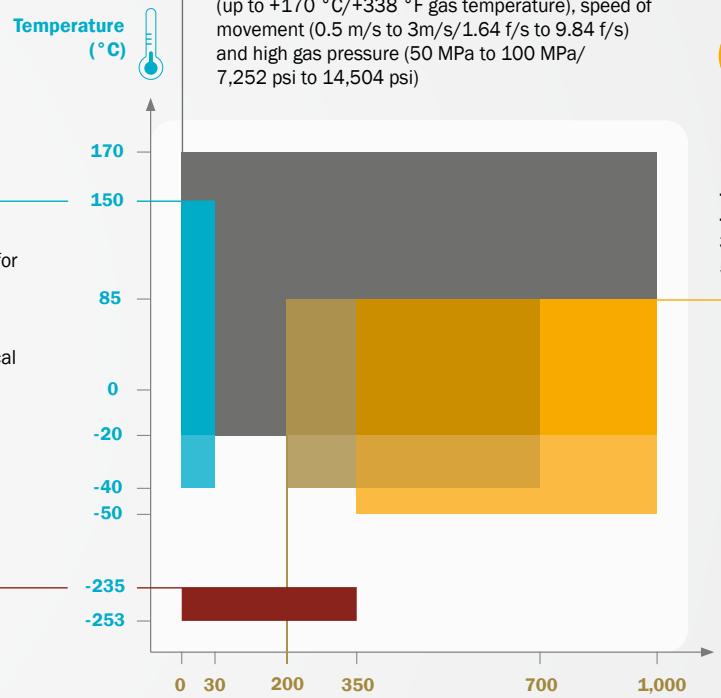
Challenges
Challenging combination of temperature (up to +170 °C/+338 °F gas temperature), speed of movement (0.5 m/s to 3m/s/1.64 f/s to 9.84 f/s) and high gas pressure (50 MPa to 100 MPa/ 7,252 psi to 14,504 psi)

Tank to Fuel Cell

-40 °C to +150 °C/
-40 °F to +300 °F
0 MPa to 3 MPa/
0 psi to 435 psi

Applications
Proportional and safety valves for low pressure range, connectors

Challenges
Cleanliness of materials is critical due to risk of contamination of the fuel cell



Dispenser & Vehicle Fuel Tank CGH_2

-50 °C to +85 °C/
-58 °F to +185 °F
35 MPa to 100 MPa/
5,076 psi to 14,504 psi

Applications
Tank nozzle and inlet, safety valve

Challenges
- Risk of H_2-permeation through sealing material and interface leakage between seal and counter surface
- Seals at pressures >30 MPa/4,351 psi with PEEK Back-up Rings to avoid gap extrusion (size of the sealing gap crucial)

Storage & Transportation LH_2/CcH_2

-253 °C to +235 °C/-423 °F to +455 °F
0 MPa to 35 MPa/0 psi to 5,076 psi

Applications
Cryotanks, fluid connectors, couplings, valves

Challenges
- Risk of brittle fracture
- Elastomers are not suitable

Storage & Transportation CGH_2

-40 °C to +85 °C/-40 °F to +185 °F
20 MPa to 70 MPa/2,901 psi to 10,153 psi

Applications
High pressure tanks, valves, flanges for pipelines

Challenges
- Risk of H_2-permeation through sealing material, and interface leakage between seal and counter surface
- Seals at pressures >30 MPa/4,351 psi with PEEK Back-up Rings to avoid gap extrusion (size of the sealing gap crucial)

LH_2: Liquid hydrogen | **CcH_2:** Cryo-compressed hydrogen | **CGH_2:** Compressed gaseous hydrogen

Temperature and pressure scales display the ranges of the sealing applications in an exemplary way.

Key Applications

CONNECTORS

Connectors are everywhere in the hydrogen supply chain and reliable sealing is vital to maintain efficiency and reliability whether liquid or gaseous hydrogen is being transported. Seals must be able to operate between high and low pressures and low to very low temperatures.

TRELLEBORG SOLUTION

- O-Rings and O-Ring with Back-up Ring for high pressure
- XploR™ S-Seal
- Turcon® Variseal® H and Turcon® Variseal® HF
- Wills Rings® metal seals

HIGH-PRESSURE VALVES

High-pressure valves at filling stations and in compressors control the flow of hydrogen into and out of tanks. LH_2 is stored at cryogenic conditions and CGH_2 at extreme high pressures, making high-performance sealing solutions crucial. Seals in high-pressure valves must withstand pressures of up to 100 MPa/14,504 psi and temperatures between -50 °C to +85 °C/-58 °F to +185 °F.

TRELLEBORG SOLUTION

- Orkot® bearings and HiMod® advanced composite bearings
- Turcon® Variseal® MC and Turcon® V-Stack
- O-Rings and Back-up Rings
- Zurcon® U-Cup RU9

LOW-PRESSURE VALVES

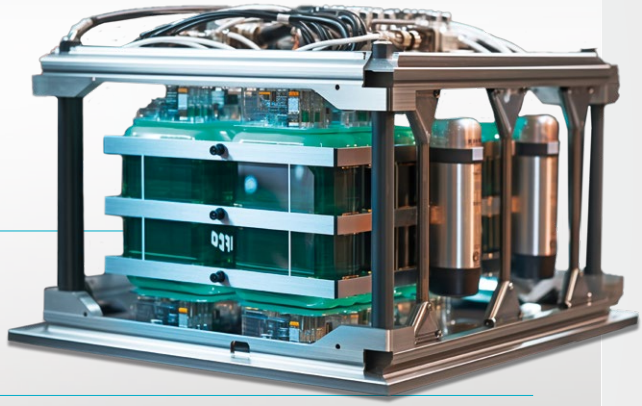
Low-pressure valves are commonly used between the electrolysis process and compression of hydrogen. These valves function at pressure below 10 MPa/1,450 psi. The expansion behavior of hydrogen leads to rising temperatures in the application and seals must function at temperatures between -40 °C to +150 °C/-40 °F to +302 °F.

TRELLEBORG SOLUTION

- O-Rings
- Wills Rings® metal seals
- Engineered molded parts
- Turcon® Variseal® H and Turcon® Variseal® HF
- Valve tappet seals

ELECTROLYSERS

Electrolysers operate at temperatures between +50 °C to +100 °C/+122 °F to +212 °F and pressures up to 8 MPa/ 1,160 psi. Seals play a critical role in ensuring efficiency and protecting hardware from electrochemical attacks.

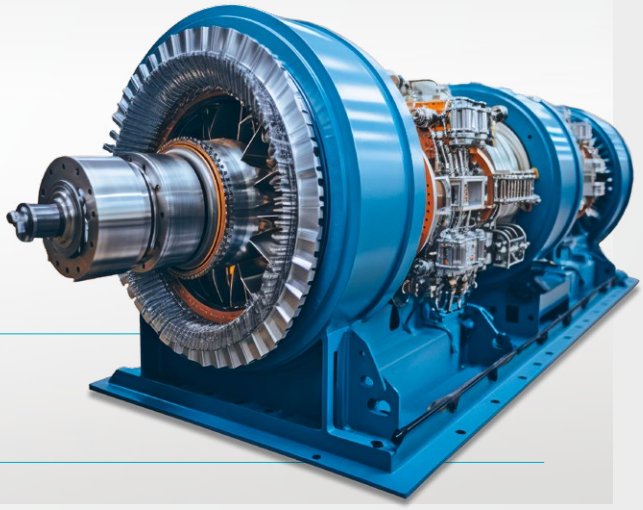


TRELLEBORG SOLUTION

- O-Rings
- HMF Flatseal™ flat gaskets and frame gaskets
- Multicomponent gaskets – rubber-to-metal or rubber-to-plastic
- Engineered molded seals

HYDROGEN TURBINES

Hydrogen turbines are natural gas turbines transitioned to blended hydrogen-natural gas turbines to generate electricity with the intention to phase out natural gas altogether. Components within turbines must be able to withstand high temperatures and be compatible with various gas mixtures and resist rapid gas decompression.



TRELLEBORG SOLUTION

- Wills Rings® metal seals
- Turcon® Variseal® H and Turcon® Variseal® HF
- Custom engineered plastic bearings

HYDROGEN COMPRESSORS

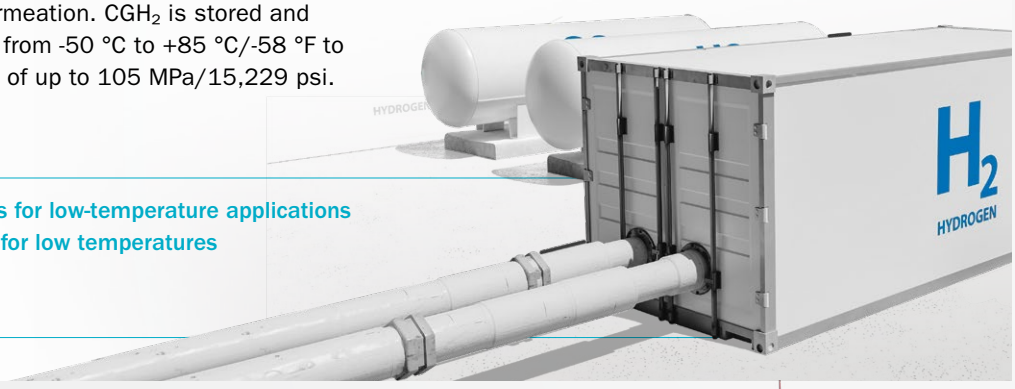
Hydrogen compressors require high-performance sealing solutions to protect hardware and prevent leakage, which can operate at speeds up to 4 m/s or 13 ft/s, a wide temperature range, from -40 °C to +200 °C/-40 °F to +392 °F, and very high pressures, up to 100 MPa/14,504 psi.

TRELLEBORG SOLUTION

- Hydraulic rod and piston seals, e.g. Turcon® Variseal® M2 and Turcon® Variseal® W2
- Specially designed piston ring systems
- Advanced thermoplastic solutions

CGH_2 STORAGE & TRANSPORT

CGH_2 requires sealing solutions suitable for use at low temperatures and high pressures, while minimizing the sealing gap and resisting permeation. CGH_2 is stored and transported at temperatures from -50 °C to +85 °C/-58 °F to +185 °F, with high pressures of up to 105 MPa/15,229 psi.



TRELLEBORG SOLUTION

- H_2Pro™ elastomer materials for low-temperature applications
- O-Rings and Back-Up Rings for low temperatures
- Turcon® Variseal®
- Metal C-Rings

LH_2 STORAGE & TRANSPORT

LH_2 is stored and transported at cryogenic conditions; our family of metal and PTFE seals is suitable for sealing in extremely low-temperature environments.

TRELLEBORG SOLUTION

- Wills Rings® metal seals
- Turcon® Variseal® H and Turcon® Variseal® HF

HYDROGEN AUTOMOTIVE APPLICATIONS

INTERNAL COMBUSTION ENGINES

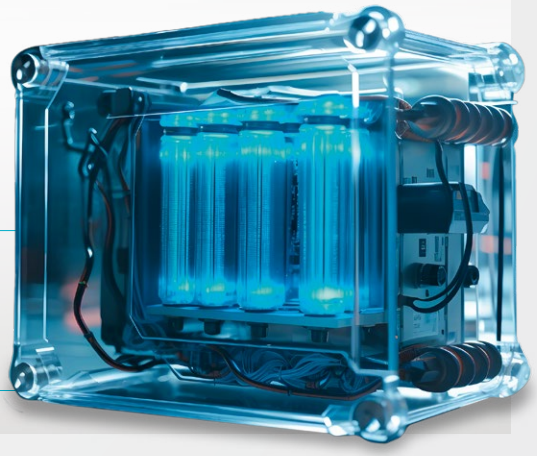
Internal combustion engines burn hydrogen in a similar way to gasoline or diesel. Beside the obvious change of the tank and feeding lines, the injection system needs to be adapted. Depending on the design of the injectors and position of the seal, they must be able to operate in a wide temperature range of -40 °C to +150 °C/-40 °F to +300 °F and under high pressures, up to 6 MPa/870 psi, and prevent leakage to ensure passenger safety.

TRELLEBORG SOLUTION

- Multicomponent parts
- Static seals – typically O-Rings and engineered molded parts
- Rubber-to-metal bonded gaskets

HYDROGEN FUEL CELL

Hydrogen fuel cell applications are especially challenging for seals, since they operate at a wide temperature range of +50 °C to +100 °C/+122 °F to +212 °F, and pressures up to 8 MPa/1,160 psi, with a significant risk of electrochemical attack which can damage seals and hardware.



TRELLEBORG SOLUTION

- Multicomponent gaskets – rubber-to-metal or rubber-to-plastic
- HMF FlatSeal™ flat gaskets and frame gaskets
- O-Rings
- Engineered molded parts

Proven Performance

Trelleborg's ever-expanding portfolio of sealing materials and profiles is proven for use in hydrogen production, storage, usage and transportation applications.

Due to a lack of established certification standards to demonstrate the performance of hydrogen sealing materials, historical standards used in other sectors have been applied with limited degrees of relevance for real-world hydrogen applications.

Trelleborg leverages its state-of-the-art in-house R&D facilities to continually push the boundaries of hydrogen sealing validation. Our experts designed proprietary test programs to prove the performance of the H_2Pro™ range, providing customer confidence in the materials. These tests are based on existing and enhanced versions of accepted standards and adapted to real-world hydrogen application conditions in advanced testing rigs.

HYDROGEN MATERIAL TESTING

Oxygen aging (according to ASTM D572 or ISO 188)

Ozone aging (according to ISO 1431-1)

Permeation (based on ISO 2782-1)
Using gas chromotography to evaluate samples, our tests determine permeation coefficients using the differential pressure method. Using helium as an appropriate proxy for hydrogen, we investigate the influence of pressure and other factors on the permeation properties of each material. From these results an approximate figure for hydrogen permeation is calculated. Further validation with hydrogen is ongoing.

Endurance Validation (based on a proprietary version of ISO 19880-3, UN ECE R134, EC79, ISO 12619-2, CSA ANSI HGV 3.1, ISO 17268 & SAE J2600)
These tests analyze materials in close to real world hydrogen applications. Pressure cycle tests are performed on O-Rings at pressures of 35 MPa and 70 MPa/5,076 psi and 10,153 psi. The test samples experience 20,000 pressure cycles at up to 125 percent of the original pressure at room temperature (+23 °C/+73 °F) and extreme application temperature limits. Decompression speeds are set at five and 10 seconds, reflecting real-life conditions. We analyze leakage performance as well as resistance to RGD, extrusion and thermal degradation.

Hydrogen Compatibility and Rapid Gas Decompression (RGD) (based on a proprietary version of ISO 17268)
We evaluate sealing materials for their ability to resist damage from hydrogen diffusion and rapid depressurization. Enhancing existing standards, such as SAE J2600, ISO 17268, EC 79 and CSA ANSI CHMC 2, samples are immersed in hydrogen at pressures of 10 MPa, 35 MPa and 70 MPa/1,450 psi, 5,076 psi and 10,153 psi at application temperatures of -40 °C, room temperature (+23 °C), +80 °C and +130 °C/-40 °F, room temperature (+73 °F), +176 °F and +266 °F. After 168 hours, the pressure is quickly released.

Material samples pass the test if:
- RGD causes no cracking
- Swell is less than 25 percent
- Shrinkage is less than 1 percent
- Weight change is less than 10 percent

UNDERSTANDING RGD

Visit the exhibit in our Virtual Showroom to learn about RGD and how this poses a unique challenge for sealing materials.

MATERIAL DATA

ELASTOMERS

	Compound	Material Description	Hardness (Sh A)	Temperature	Pressure
EPDM	E5T30	Low-pressure grade	50	-45 °C to +150 °C -49 °F to +302 °F	<=10 MPa/1,450 psi
	E7T30	Medium-pressure grade, low compression set	70	-45 °C to +150 °C -49 °F to +302 °F	35 MPa/5,076 psi
	E8T24	Robust RGD-resistant, low-temperature grade	80	-50 °C to +150 °C -58 °F to +302 °F	70 MPa/10,153 psi
	E8T31	Medium-high pressure grade	80	-45 °C to +150 °C -49 °F to +302 °F	35 MPa/5,076 psi
	EBT25	Robust RGD-resistant, low-temperature grade	86	-50 °C to +150 °C -58 °F to +302 °F	70 MPa/10,153 psi
FKM	VCT14	Standard FKM	75	-35 °C to +200 °C -31 °F to +392 °F	35 MPa/5,076 psi
	V8T3G	Medium-pressure grade	80	-45 °C to +200 °C -49 °F to +392 °F	35 MPa/5,076 psi
	V8T73	Medium-pressure grade	80	-45 °C to +200 °C -49 °F to +392 °F	35 MPa/5,076 psi
	V9T82	Robust RGD-resistant, low-temperature grade	90	-45 °C to +200 °C -49 °F to +392 °F	70 MPa/10,153 psi
Silicone	FCT30	Automotive fluoro vinyl methyl silicone rubber (FVMQ) grade	75	-50 °C to +175 °C -58 °F to +345 °F	<=10 MPa/1,450 psi
	SCT31	Low-temperature grade	75	-120 °C to +230 °C -184 °F to +446 °F	35 MPa/5,076 psi
	S8T82	Low-temperature PVMQ grade for high pressures	80	-120 °C to +200°C -184 °F to +392 °F	70 MPa/10,153 psi
Zurcon® PU	ZLT	Ultra-low temperature PU H_2 grade	93	-60 °C to +110 °C -76 °F to +230 °F	70 MPa/10,153 psi
	Z22	Low-temperature standard PU	93	-45 °C to +110 °C -49 °F to +230 °F	70 MPa/10,153 psi

PLASTICS AND METALS

	Compound	Material Description	Material Family	Temperature	Pressure
Turcon® PTFE	MH6	For dynamic and cryogenic sealing	PTFE	-200 °C to +260 °C -328 °F to +500 °F	100 MPa/14,504 psi
	MH8	For dynamic and cryogenic sealing	PTFE	-200 °C to +260 °C -328 °F to +500 °F	100 MPa/14,504 psi
Zurcon® Engineered Plastic	Z80	For static cryogenic sealing	Ultra-high-molecular-weight polyethylene (UHMWPE)	–200 °C to +80 °C -328 °F to +176 °F	100 MPa/14,504 psi
	DH3	For LH_2 static sealing	Polychlorotrifluoroethylene (PCTFE)	-270 °C to +170 °C -454 °F to +338 °F	100 MPa/14,504 psi
	Z43	Superior extrusion resistance	PEEK	-200 °C to +260 °C -328 °F to +500 °F	100 MPa/14,504 psi
Metal	1H	For static cryogenic sealing	316L stainless steel	-270 °C to +750 °C -454 °F to +1,375°F	200 MPa/29,000 psi

Trelleborg is a world leader in engineered polymer solutions that protect essential applications in demanding environments. Its innovative solutions accelerate performance for customers in a sustainable way.

Trelleborg Sealing Solutions is a leading developer, manufacturer and supplier of precision seals, bearings and custom-molded polymer components. It focuses on meeting the most demanding needs of aerospace, automotive and general industrial customers with innovative solutions.

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