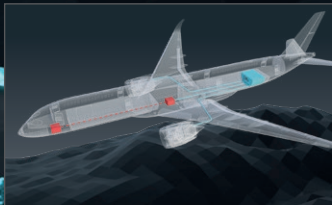


# Polymer Solutions for Hydrogen Aircraft

**ACCELERATING INNOVATION FOR  
MORE SUSTAINABLE AIR TRAVEL**



# Hydrogen Power – A Fast-Growing Sector

As airlines take immense strides towards emissions-free, medium and long-haul commercial flights, powered by major government investment programs, the first crewed liquid hydrogen aircraft has already taken to the skies. With an eye on this critical development in more sustainable air travel, Trelleborg Aerospace has worked on test programs for over five years to develop seals suitable for hydrogen-powered aircraft.

**Innovative  
testing  
capabilities**

**Fully validated  
gas-tight  
sealing**

**Premium,  
proven  
materials**

**Global  
expertise and  
local service**

Sealing hydrogen is notoriously difficult due to its challenging chemical characteristics, even in the general industry. The use of hydrogen in aircraft requires almost 100% containment of gaseous hydrogen as the accumulation of even small amounts of hydrogen in a closed vehicle, such as an aircraft, could be fatal.

**Trelleborg is actively developing seals and sealing materials with low permeation properties, which achieve virtually leak-free sealing. Our portfolio contains a full range of polymer materials, as well as metal seals.**

The Trelleborg Aerospace team tested more than 40 seal geometries and 26 materials to find the best base components for highly effective low-leakage seals. The most suitable were combined into new seal designs with a significant reduction in permeability and leakage.

## Features & Benefits

- **Specifically engineered materials** meet sealing requirements across the hydrogen value chain
- **Validated** to meet relevant standards and directives
- **Proven** to withstand challenging application requirements, including resistance to leakage and permeation, high pressures, extreme temperatures and rapid gas decompression
- **Excellent** application-specific wear and extrusion **properties, extending service life** and **reducing the total cost** of ownership
- **Easily assembled sealing components** reduce maintenance costs

## Our Global Network

**Trelleborg Aerospace collaborates with major aerospace original equipment manufacturers (OEMs) to develop and supply innovative polymer solutions, which maximize the performance of their equipment. We do this through:**

- **Engineering expertise:** We offer collaborative engineering from prototype development to market launch
- **R&D capabilities:** We develop and test the performance of seal designs and materials in dedicated in-house facilities to ensure our solutions meet customer requirements
- **Advanced manufacturing processes:** Global resources produce custom solutions using advanced technologies
- **Advanced delivery:** Our global network provides a range of supply chain services, such as rapid delivery and special kitting and packaging programs to help avoid downtime

## Unrivalled Product Portfolio

**Engineered with precision and expertise, our seals ensure uncompromised performance and reliability. We offer a comprehensive range of sealing solutions designed for innovative hydrogen applications, from standard solutions to tailor-made components.**

- **Cryogenic Variseal® spring-energized seals:** The Variseal® line offers multiple spring types, allowing for specification based on optimal seal contact pressure. With the adaptability of a machined seal jacket, we can create seals that withstand the most demanding conditions.
- **Wills Rings® metal static seals:** Available in various forms, including O-Rings, C-Rings and omega seals, Wills Rings® combine flexibility and high-pressure capabilities. Their efficiency can be further enhanced with PTFE or metal coatings.
- **Custom-designed sealing components:** Leveraging our extensive product portfolio and expertise, we can combine different seal designs into custom solutions to achieve specific performance targets.



**Cryogenic  
Variseal® spring-  
energized seals**



**Wills Rings®  
metal static  
seals**

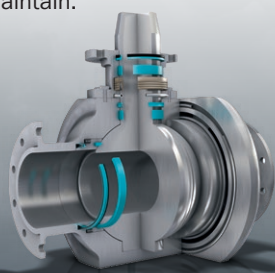


# Application Spotlight

We are at the forefront of innovation in the aerospace sector. Our high-performance solutions are instrumental in safeguarding the reliability, efficiency and safety of aircraft, spanning a wide range of applications.

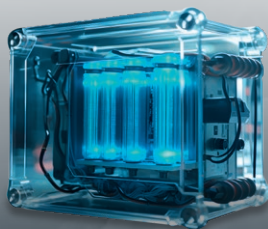
## COUPLINGS

Regardless of the storage methods, hydrogen must be transferred safely from the storage tank to the end-use equipment, such as the aircraft engine or a fuel cell. The couplings and fittings must be efficiently sealed, but still able to open and close easily for overhaul and repair. We offer a range of polymer seals that are virtually leak-free and easy to handle and maintain.



## FUEL CELLS

Hydrogen fuel cell applications are especially challenging for seals, since they operate at temperatures from +50 °C to +100 °C/+122 °F to +212 °F, and pressures up to 8 MPa/1,160 psi. Seals must be able to withstand these operating conditions, demonstrate chemical compatibility and have low-leach properties to ensure efficient fuel cell performance.



## COMPRESSED HYDROGEN GAS (CGH<sub>2</sub>) FOR STORAGE AND TRANSPORT

CGH<sub>2</sub> 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.

We offer sealing solutions for storing and transporting CGH<sub>2</sub>, which are suitable for use at low temperatures and high pressures, can withstand rapid gas decompression (RGD) and are resistant to permeation.



## DID YOU KNOW...

... that since 2022, Trelleborg has been an **Airbus partner in the ZEROe project**, which aims to develop a hydrogen-powered commercially viable aircraft by 2035. Trelleborg is responsible for developing the seals for the fuel lines and other similar applications.

**ZEROe**

# ight

## LIQUID HYDROGEN (LH<sub>2</sub>) FOR STORAGE AND TRANSPORT

For storing and transporting LH<sub>2</sub> at cryogenic conditions, our metal seals and special polymer seals are suitable for sealing in extremely low temperature environments.



## Unique Characteristics

Hydrogen has unique properties and requires innovative, tailor-made sealing solutions:



**PERMEATION** – hydrogen is the smallest molecule and can permeate sealing materials.



**EXTREMELY LOW TEMPERATURES** – hydrogen can be stored as a liquid or a gas. CGH<sub>2</sub> requires low temperatures for refueling and LH<sub>2</sub> is stored at cryogenic temperatures of -253 °C/-423 °F.



**VERY HIGH PRESSURES** – to make it a more efficient energy source, hydrogen is compressed, with pressures up to 105 MPa/ 15,229 psi, to increase volumetric energy density.



**RAPID GAS DECOMPRESSION** – when pressure in a hydrogen application decreases, hydrogen molecules are released from the seals, which can damage or even destroy sealing materials.



# Testing of Material Properties

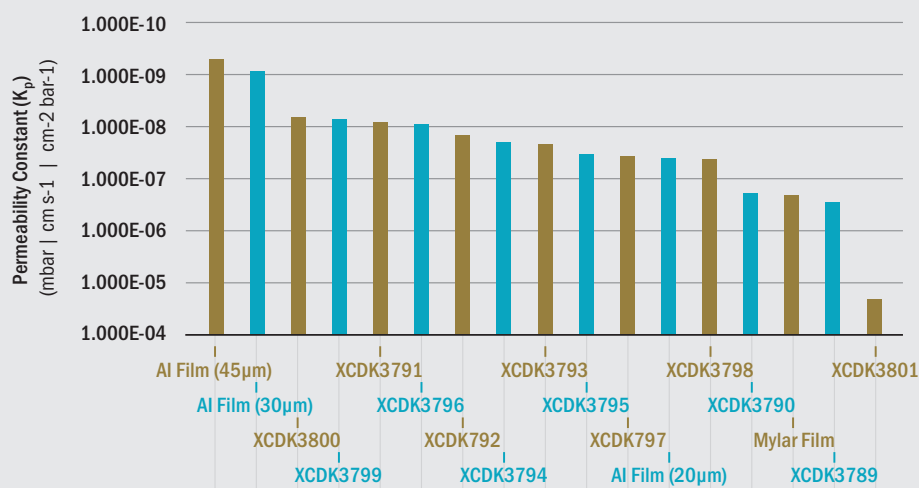
**H<sub>2</sub>Pro™ MATERIALS** – Polymers and metals suitable for use with hydrogen

	Compound	Material Description	Material Family	Temperature	Pressure
<b>Turcon® PTFE</b>	<b>MH6</b>	For dynamic and cryogenic sealing	PTFE	-200 °C to +260 °C/-328 °F to +500 °F	100 MPa/14,504 psi
	<b>MH8</b>	For dynamic and cryogenic sealing	PTFE	-200 °C to +260 °C/-328 °F to +500 °F	100 MPa/14,504 psi
<b>Zurcon® Engineered Plastic</b>	<b>Z80</b>	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
	<b>DH3</b>	For LH <sub>2</sub> static sealing	Polychlorotrifluoroethylene (PCTFE)	-270 °C to +170 °C/-454 °F to +338 °F	100 MPa/14,504 psi
	<b>Z43</b>	Superior extrusion resistance	PEEK	-200 °C to +260 °C/-328 °F to +500 °F	100 MPa/14,504 psi
<b>Metal</b>	<b>1H</b>	For static cryogenic sealing	316L stainless steel	-270 °C to +750 °C/-454 °F to +1,375 °F	200 MPa/29,000 psi

## PERMEABILITY TESTING

Using a purpose-built light gas cryogenic test cell, we test the permeability of seal designs and materials from -196 °C to +85 °C/-320 °F to +185 °F, and with pressures ranging from vacuum to 13.2 MPa/1,915 psi. We have evaluated the permeability performance of 26 polymer materials. Among these we tested PTFE, CTFE, PEEK, FEP, UHMWPE and others.

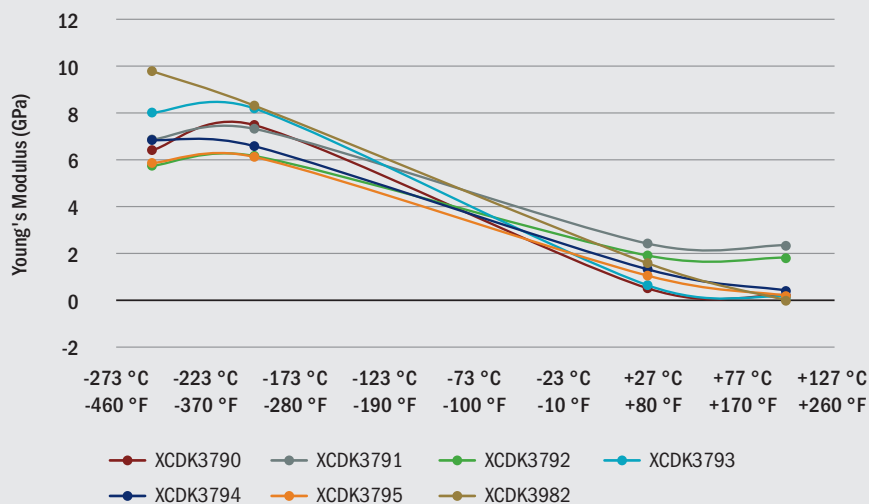
**Gas Permeability** – Materials tested with helium



## ULTIMATE STRESS TESTING

Since seal materials must remain flexible to effectively seal at low materials, we perform detailed testing of polymer and metal materials and seal profiles, across a full range of temperatures from -253 °C to +100 °C/-424 °F to +212 °F, simulating environments containing liquid hydrogen and the service environments for gaseous hydrogen.

**Material Flexibility Testing** – Across temperatures with helium and nitrogen



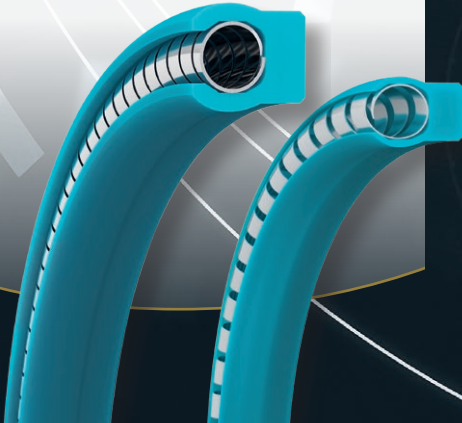
# Validated Solutions

We combined the most successful materials and designs from our proprietary test program in a portfolio of new hydrogen seal designs with a significant reduction in permeability and leakage.

The testing gave a clear picture of the permeability levels that can be expected from each design and it will help us select the most effective solution for various applications.

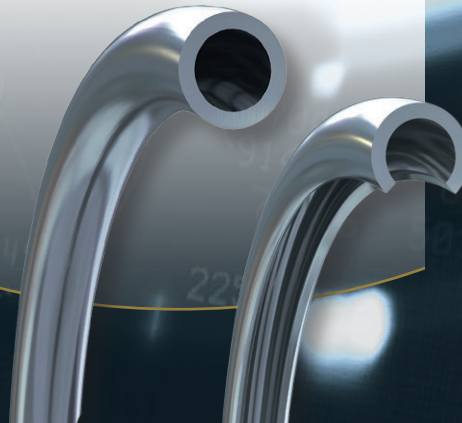
## **Variseal® Spring-Energized Seals**

Upon completion of permeability testing, we evaluated the performance of these materials using Variseal® seal designs. The resulting 17 Variseal® profile and material options were performance tested at several temperature and pressure stages.



## **Wills Rings® Metal Static Seals**

We conducted performance tests of 22 Wills Rings® metal seals to validate a range of sealing solutions for use with LH<sub>2</sub>. Through these tests, we have gained unique insight into the relationship between hardware surface finish, seal coating, seal contact force and the sealing efficiency.



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.

[WWW.TRELLEBORG.COM/SEALS](http://WWW.TRELLEBORG.COM/SEALS)



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