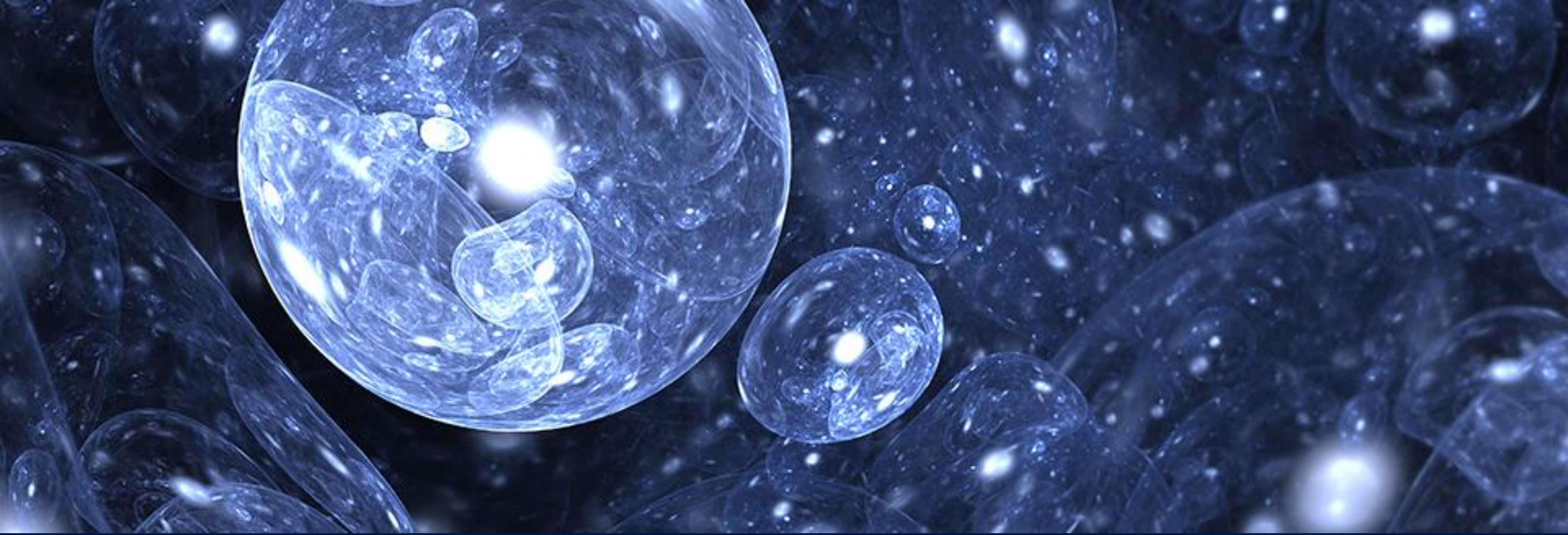


Introduction LH2 Kiwa Group

LH2KC 4 June 2025

Harald Ophoff

Digital and
Cyber Solutions

Sustainability Service

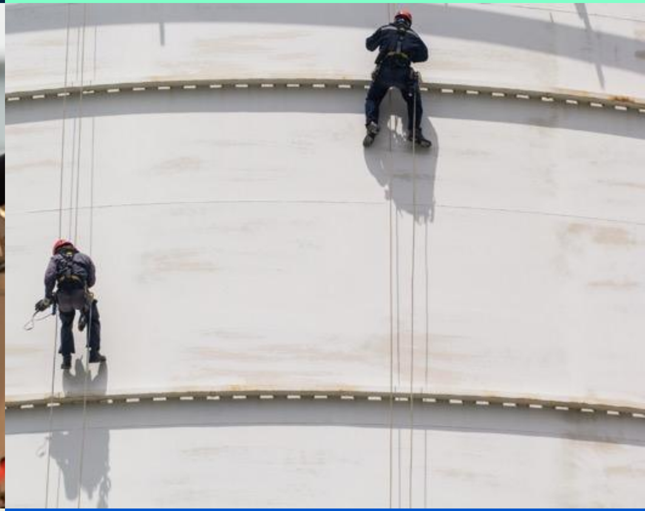
Food, Feed,
Argriculture

Industrial Services

Energy Transition

Medical Devices

Product Testing
and Certification



Business Assurance

Who we are

Kiwa is

Active worldwide

Founded in 1948 in NL

Part of the SHV family of companies

Kiwa has

Offices in 35+ countries

A network of partners and agents

A revenue of 1.3 billion in 2023

~12.000 employees

Kiwa, your partner in Automotive!
Alternative Fuels and Pressure Products standards

- UNECE R10
- UNECE R110
- UNECE R67
- ISO 19880
- UNECE R134
- GTR. No. 13
- H2 directive EC 79-2009
- EN 17339
- ISO 11119-3
- ISO 15500

- ANSI/CSA NGV & HGV series
- DOT approvals
- KHK
- ADR / PED / TPED approvals

ISO 17025
RVA L 248

KBA
Benannter TD
KBA-P 00033-12

RDW

E1 E4
e1 e4

kiwa gecertificeerd ISO 15500

C US

0063

Kiwa Hydrogen specialists contribute to Toyota Mirai

- Testing of Type IV H2 cylinders for Automotive application
- Testing high pressure H2 vehicle components
- 700 bar / -40 °C / 85 °C
- Technical Service R134 for the RDW, KBA and STA

From March this year it will be in the showroom, the new hydrogen powered Toyota Mirai. As usual, the Japanese car manufacturer did not go overnight in the development of its new vehicle and invested heavily in new components and techniques. Toyota turned to Kiwa to test new high pressure components for the new Mirai's hydrogen powertrain.

One of the biggest challenges facing hydrogen car manufacturers is the storage of hydrogen gas. Daan ten Have of Kiwa Alternative Fuels and Pressure Products explains: 'This has to be done under high pressure to keep the size of the hydrogen tanks within limits. Those tanks and their components have to meet strict requirements and are therefore extensively tested under the most extreme conditions. Manufacturers have been able to do this for more than ten years in Kiwa's hydrogen lab in The Netherlands, one of the few in Europe and even far beyond.'

ET GmbH

Your professional partner for hydrogen testing and development | Dr. Bernhard Strauß

kiwa

ET GmbH

- > 25 years' experience
- International service provider
- Specialized in safe hydrogen testing
- Highly qualified team
- ISO 9001 and ISO 27001 certified

Company Background

Heritage: MBB -> DASA -> Airbus	
since 1958	Development and test of aerospace systems
1970-2000	ARIANE 4 and 5 development (liquid hydrogen and oxygen)
1990-2000	Terrestrial applications of space technologies • Hydrogen supply for buses on airport Munich hydrogen project • Hydrogen system in AIRBUS/Tupolev aircraft project • Cryogenic systems and hydrogen infrastructure
since 1997	**ET EnergieTechnologie GmbH** • Transfer of know-how and infrastructure to ET • Development and test of innovative hydrogen systems • Buildup of the world's leading hydrogen storage development and test center • Buildup of fuel cell laboratory (18 testbenches with 1 MW total power output) • Buildup of Test Facility for Cryogenic Material Characterization
Sep 2024	**ET becomes part of Kiwa**

Overview ET Facilities

- Site located in Brunnthal near Munich
- Total Area: 10.000 m2

Divisions

High Pressure Hydrogen
Worlds largest high pressure hydrogen test facility

Cryogenic Hydrogen (sLH2,LH2)
Unique know-how and test facilities for liquid hydrogen technologies

Fuel Cell Testing and Development
Fully equipped fuel cell laboratories – 1 MW total power output

Industry Sectors and Main Customers

Automotive Industry
OEMs and Suppliers from Asia, Europe and USA

Aeronautics and Space
ESA and European space companies,
Aircraft manufacturers from Europe and USA

Plant Construction and Shipbuilding
Industrial companies from Asia and Europe

Cryogenic Hydrogen Facilities

- Two LH2 Storage Tanks (capacity 1.7 tons)
- Superinsulated Supply Lines and Fittings,
- Three fully equipped test stands with measurement and supply systems (heat, power) for development and test of systems
- Material Characterization in LH2 under pressure up to 100 Mpa

Ready to use for tests with LH2 and sLH2

kiwa

Cryogenic Hydrogen – test services with LH2 and sLH2

Hydrogen Storage System Function:
Refueling, Defueling, Fuel Supply, Insulation Performance (dormancy), Sensors, Boil-Off Managment, Operation under tilt and roll Conditions

Component function:
Valves, Couplings (Nozzle/Receptacle), Connectors, Heat Exchangers, Sensors, Pumps

Safety:
Leakage, Hydraulic Burst Tests, Rollover, Loss of Insulation Vacuum

Material Characterization
Hydrogen Embrittlement, Tensile tests , Fatigue tests, Fracture Toughness, Crack Growth ...

With original medium liquid hydrogen

Liquid Hydrogen Experience

In Space sector:	
since 1998	Basic Research Projects: Fibre Optic Sensor systems for LHSS monitoring Slush Hydrogen Production Cryogenic Valve Sealing 2-Phase Flow Phenomena Permeation Through CFRP at LH2-Conditions Demonstration of Zero-Boil-Off Concept
since 2014	Characterization and Qualification of insulation foam for Ariane 6 Upper Stage LHSS (Thermal Conductivity, Thermal Shock, LH2-Permeability, Thermomechanical Properties, Cryopumping)
since 2016	Development and Operation of Apparatus for in-situ Material Characterization in LH2

With original medium liquid hydrogen

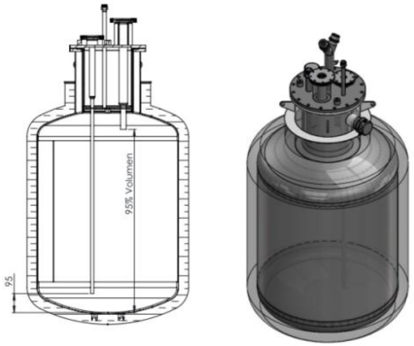
Demonstrator Tank

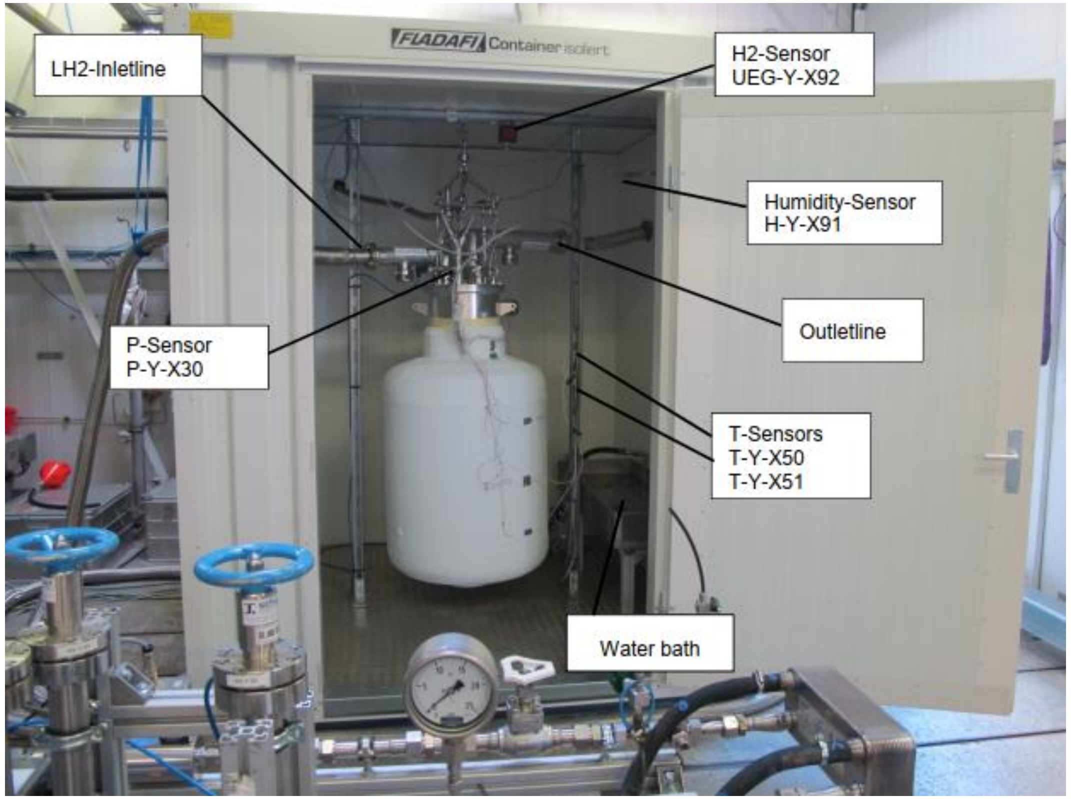
Experimental space tank (2.5 m³)

- Development of future spacecraft cryo-insulation materials
- Filling cycles with liquid hydrogen (-253 °C), 170 kg hydrogen per filling
- Tests were performed for the European Space Agency (ESA) in cooperation with Thales Alenia Space Italy

External Thermal Insulation, Humidity Experiment

Investigation of cryopumping effect on foam insulated liquid hydrogen test tank @ 35°C and 100% Humidity





Space Valve Test with LH2

Liquid Hydrogen Experience

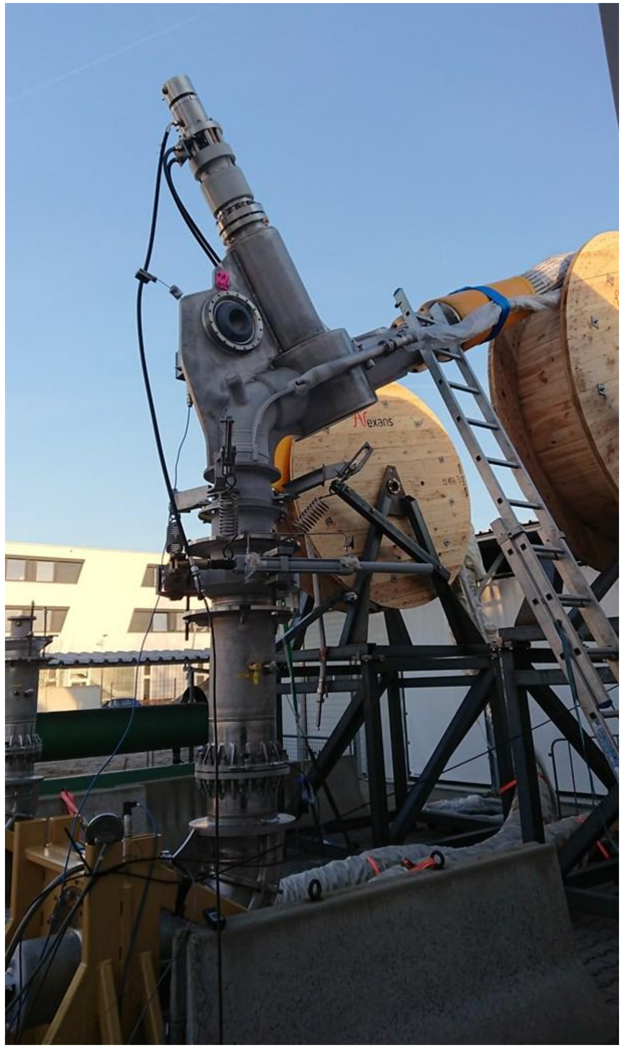
In Infrastructure/Transport sector:	
2014	Thermal cycling of workpieces under LH2 conditions
2014-2015	Characterization and Qualification of LH2-Pump for maritime Application (up to 36 m^3 LH2/h!)
2015-2016	Cryogenic Ejector for Liquid Hydrogen Plant Characterization with Hydrogen @ 10-30 bar / 22-30 K
since 2017	Characterization and Qualification of Hydrogen Transfer System Components and Subsystems for maritime application

With original medium liquid hydrogen

LH2 Pump Testing

- Pump and instrumentation submersed in LH2
- Proof of concept, functional tests of maritime pumps
- Test of submersed pumps for Truck LHSS

Components of Infrastructure/Maritime Transportation



Liquid Hydrogen Experience

More than 25 Years in Automotive sector:	
1998-2018	Contribution to special projects in the field of Automotive LHSS LH2-pumps, Valves, Heat Exchangers, Free Form LHSS, Flat LHSS
1998-2003	Characterization and Qualification of LHSS for BMW 750hL (Shown at EXPO2000 and World Tour afterwards) Support of World Tour: Infrastructure and Operation
2002-2004	Characterization and Qualification of LHSS for BMW H2R, Support of Operation in Munich and Miramas
2003-2011	Characterization and Qualification of LHSS for BMW Hydrogen 7, Support of Operation of Demonstration Fleet
2008-2015	HSS for Cryo-Compressed Hydrogen CcH2; Contribution to German Government funded Projects HySim, CryoComp, CryoSys, CryoCode (BMW, Airbus, KIT, Linde)
Since 2017	Tests of components (valves, heat exchangers, pumps, nozzles and recepacles) and LHSS for Trucks and Busses

With original medium liquid hydrogen

Truck LHSS under Test @ET

Liquid Hydrogen Experience

In Aviation sector:	
2008-2015	Contribution to German Government funded Projects HySim, CryoComp, CryoSys, CryoCode (BMW, Airbus, KIT, Linde)
2008-2009	Combined operation of subscale LHSS with FC-System
Since 2021	Comprehensive material characterization test campaigns
Since 2021	Characterization of Heat Exchangers for aircraft application
Since 2022	Test campaigns on inner tank optical and electrical installations under static and sloshing conditions
Since 2023	Several test campaigns on pipe failure cases
2023-2024	Tests of LHSS for regional aircraft
Since 2024	Tests of different Demonstrator LHSS for Flight Tests
Since 2025	Tests on cryogenic connectors for aircraft application

With original medium liquid hydrogen

Aircraft LHSS under Test @ ET

Universal Hydrogen Runs 1-MW Fuel Cell Using Liquid Hydrogen Capsules

February 27, 2024

The test was the first time a liquid hydrogen module and fuel cell powertrain were integrated, Universal Hydrogen says.

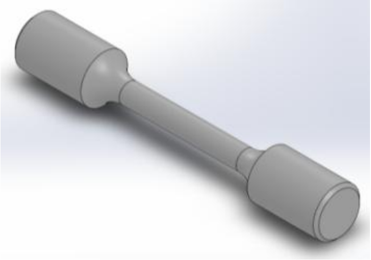
Credit: Universal Hydrogen

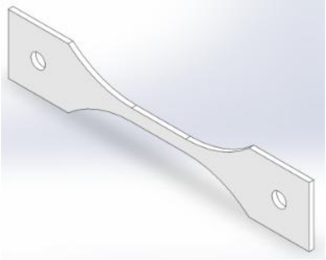
Material characterisation @ET

Basic features

Servo-hydraulic testing machine

- Explosion-proof (ATEX)
- Load: 100 kN
- Stroke: 50 mm
- Frequency: up to 25 Hz
- Specimen dimensions:
  Up to 250 mm (height) x 220 mm (diam.)
- Flexible grips & specimen geometries:
  - Round/ pipe/ plate/ sheet/ foam ...
  - Complex structures / components ...





Measurement & control

- Load
- Strain (in-situ at specimen)
- Stroke
- Acceleration
- Potential drop through specimen

- Temperature
- Pressure
- Cryogenic liquid filling level

...permanent synchronized data acquisition
(rate up to 1 kHz)

Universal testing machine for broadband application and flexible modification

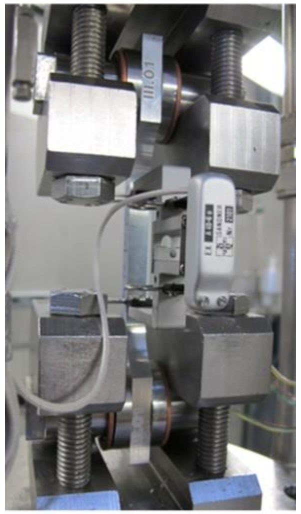
Test set-up – cryogenic conditions

L_0 L_ε At RT L_ε At LH2

Qualified test methods

Metals:

- Tensile Tests
- Fatigue Tests



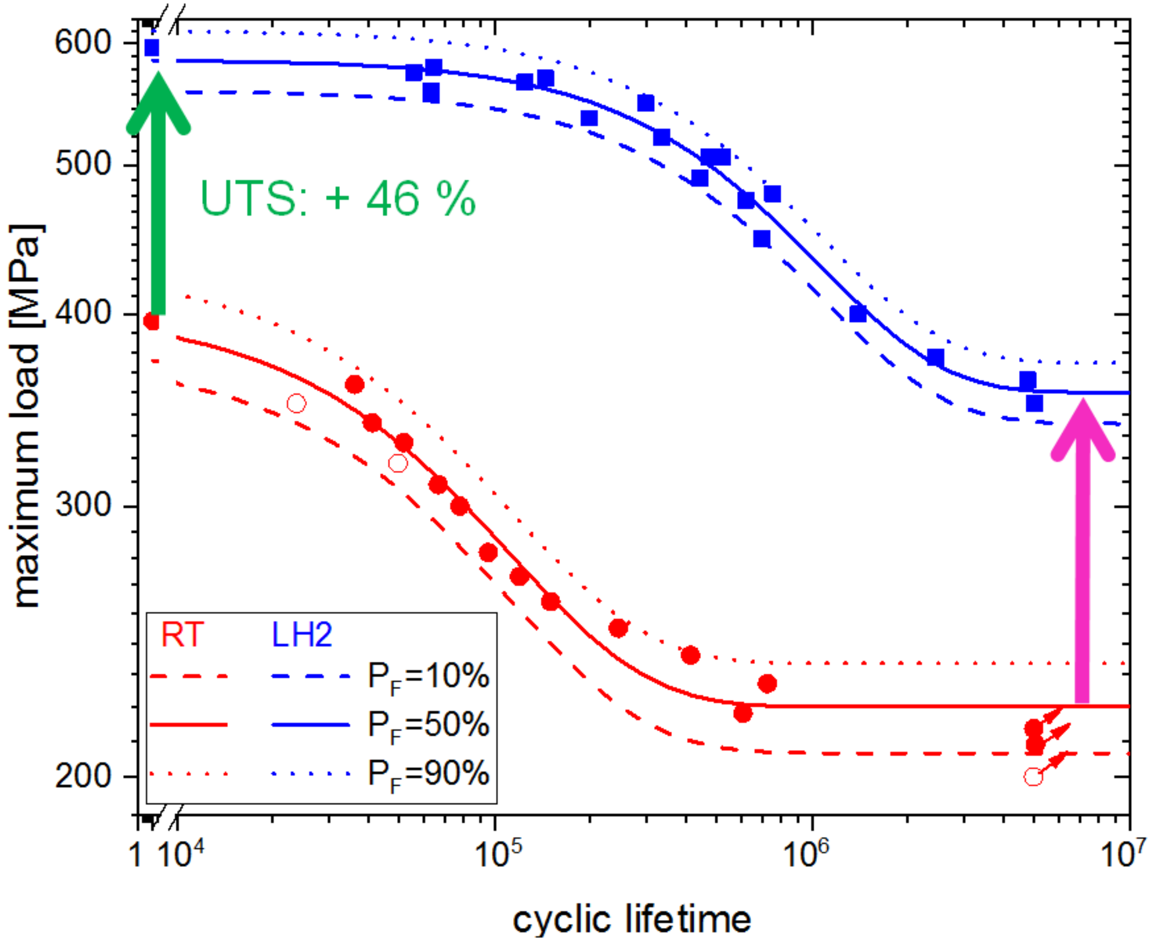
CFRP:

- Tensile Test

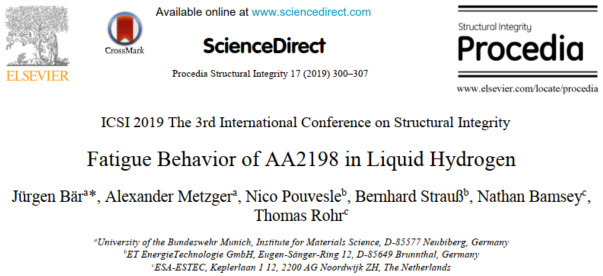
CFRP:

- Fracture Toughness
- Crack Growth

Example: Fatigue Testing in LH2



Fatigue limit: + 60 %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Procedia Structural Integrity 17 (2019) 300–307
Structural Integrity Procedia
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ICSI 2019 The 3rd International Conference on Structural Integrity

Fatigue Behavior of AA2198 in Liquid Hydrogen

Jürgen Bär[a]*, Alexander Metzger[a], Nico Pouvesle[b], Bernhard Strauß[b], Nathan Bamsey[c], Thomas Rohr[c]

[a]University of the Bundeswehr Munich, Institute for Materials Science, D-85577 Neubiberg, Germany
[b]ET EnergieTechnologie GmbH, Eugen-Sänger-Ring 12, D-85649 Brunnthal, Germany
[c]ESA-ESTEC, Keplerlaan 1 12, 2200 AG Noordwijk ZH, The Netherlands

No simple extrapolation possible to gain low temperature data

Development of test methods based on standards

- As standards do not cover cryogenic and/or high pressure conditions adapted test methods/procedures are elaborated
- qualified under cryo and/or hp conditions
- in close cooperation with ESTEC, Materials & Processes Section
- with scientific support:

Institut für Werkstoffkunde IWK

der Bundeswehr Universität München


EUROPÄISCHE NORM
EUROPEAN STANDARD
NORME EUROPÉENNE
EN ISO 12737
Deutsche Fassung
Metallische Werkstoffe — Bestimmung der Bruchzähigkeit (ebener Dehnungszustand) (ISO 12737:2010)


DEUTSCHE NORM
August 1992
Luft- und Raumfahrt
Faserverstärkte Kunststoffe
Zugversuch an einlagigen Zugflachprobekörpern
DIN 65 469

Contact:
Harald.Ophoff@kiwa.com

Thank you for *listening*

creating trust
driving progress