HyMEET Programme

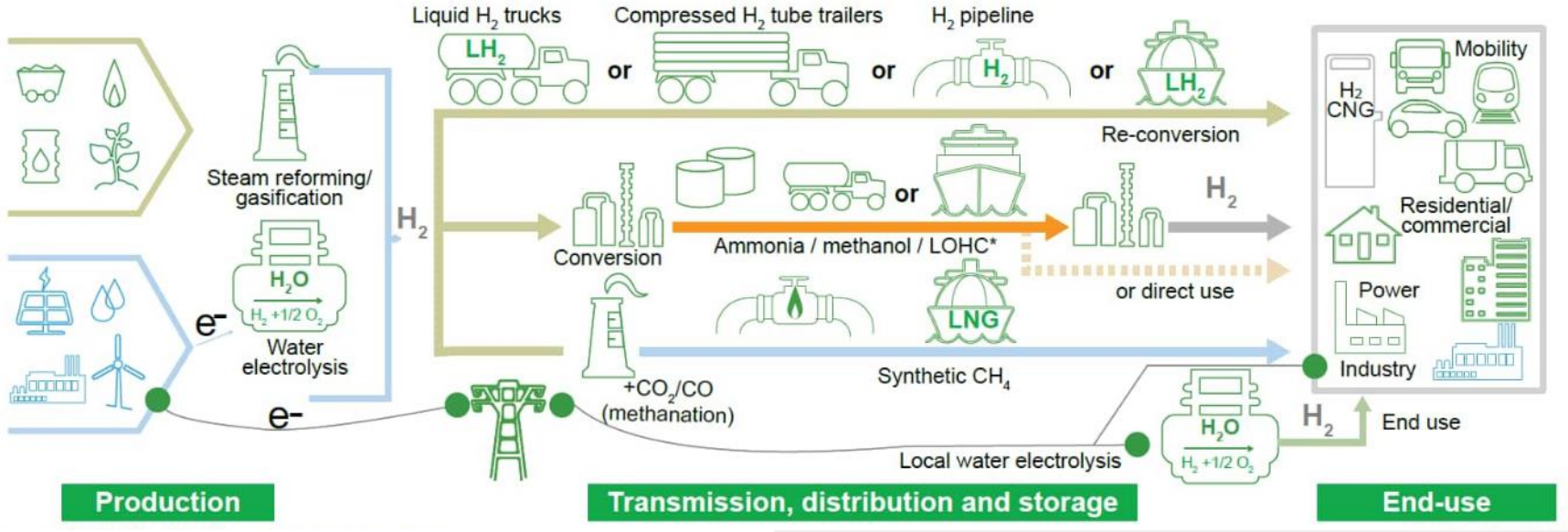
Unlock H_2 technological barriers

R&D - Engineering - Testing - Consulting - Trainings

Mechanical industries serving the hydrogene value chain

Hymeet : Cetim strategic program on H_2

To support the mechanical industry as a major player in the development of production, storage, transport and distribution sectors up to final uses.

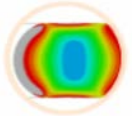


R&D road map and activities

Material expertise, characterisation and testing

- Mechanical and fatigue
- Physico-chemical characterisation
- Permeation and diffusion
- Tribological behavior
- Sealing properties

Design tools and manufacturing



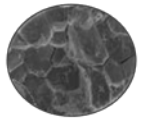
- Failure analysis & Modelling
- TP composite design and manufacturing
- Pressure equipment design & welding
- Stack manufacturing and design
- Technical cleanless

Equipment control and qualification

- Test engineering for system qualification
- Sensors evaluation and instrumentation
- Installation monitoring SHM

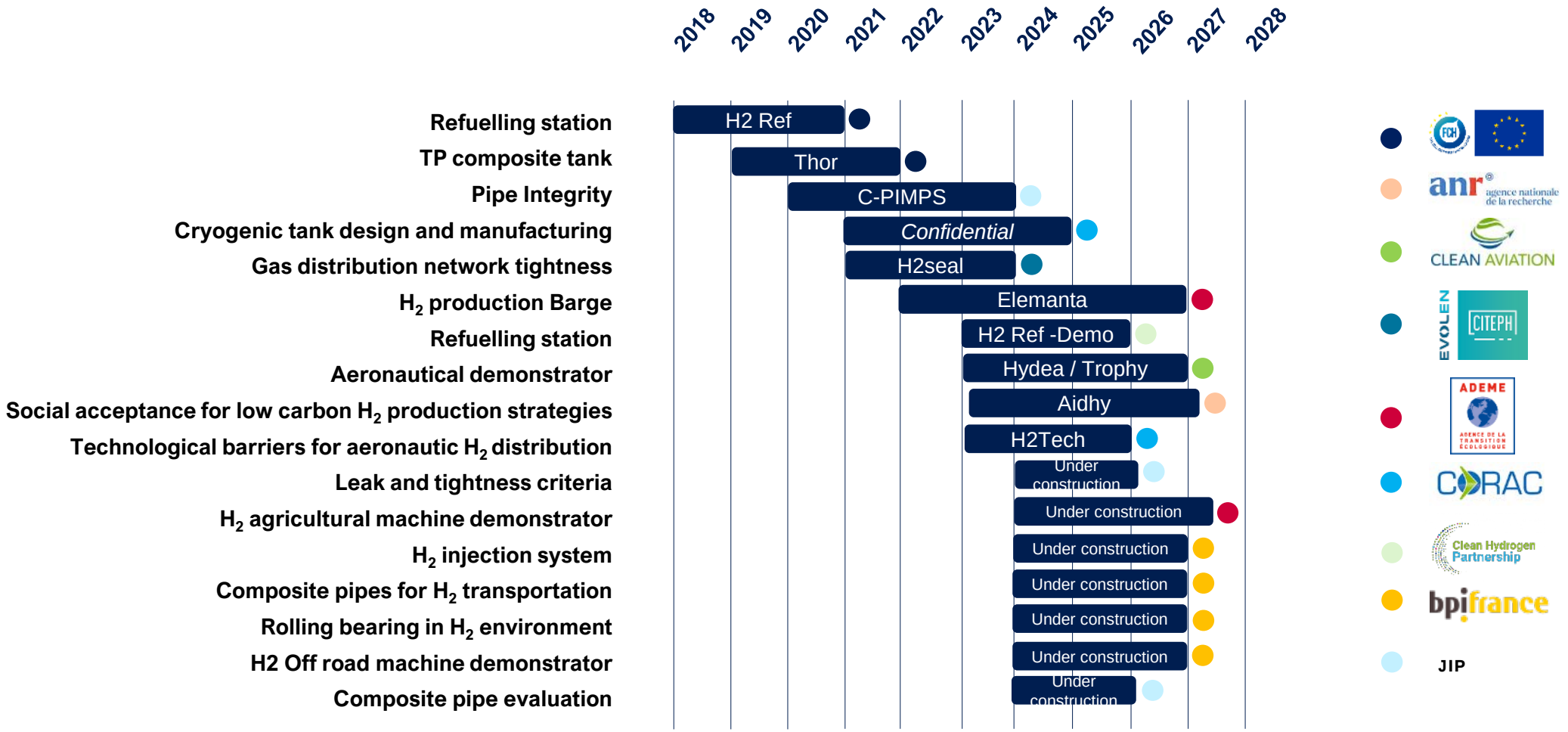
H2 associated developpements

- NH3
- CCUS



Standardization & Knowledge dissemination

Collaborative projects



Member of Hydrogen Europe Research, GERG, Nouveaux Systèmes Énergétiques

Scientific & Technologic Partnership for H_2

A PhD & MSc program

H_2 effect on fatigue properties of AISI 304 & 316 at low Temperature
Institut Pprime, UPR CNRS 3346 : **Prof. Henaff**

Fatigue damage of H_2 Pressurized Storage Equipement by Phase Field Method
IMT Nord Europe, CERI MP: **Dr. Chaki**

PHyDROMAT: Behaviour of Metallic Materials for aeronatical applications
Member of the Scientific & Strategic Committe (3 PhD)

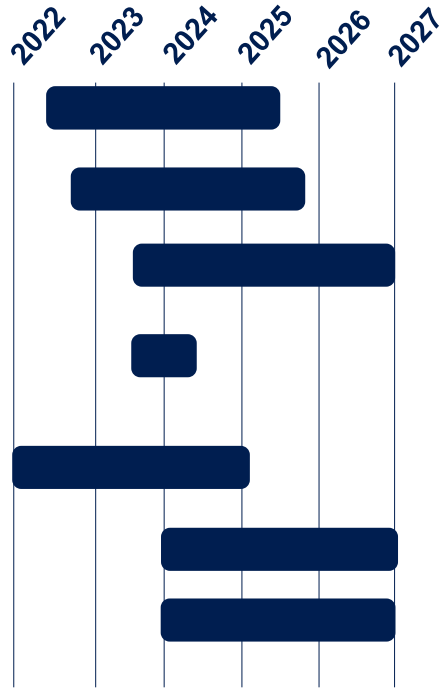
H_2 / plasticity interaction of Austenitic Stainless Steel
Kyushu University, Dpt of Mechanical Engineering: **Prof. Matsunaga**
Université La Rochelle, LaSIE UMR CNRS 7356: **Prof. Feaugas**

Flexible organic piezoelectric UT sensors for NDT & SHM of pressure tanks
Université Bordeaux, I2M UMR 5295: **Prof. Meziane**

Performance &durability of elastomer seals for Carbon-free applications
Institut Pprime, UPR CNRS 3346 : **Prof. Gigliotti**

Numerical and experimental study of valve packing: application to the reduction of fugitive hydrogen emissions
IRDL: **Prof. xxxx**

=+ 2 PhD under construction



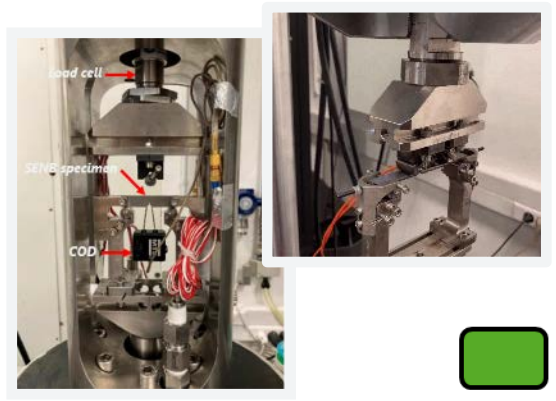
Strategic players

Air Liquide

arianeGROUP

H_2PULSE

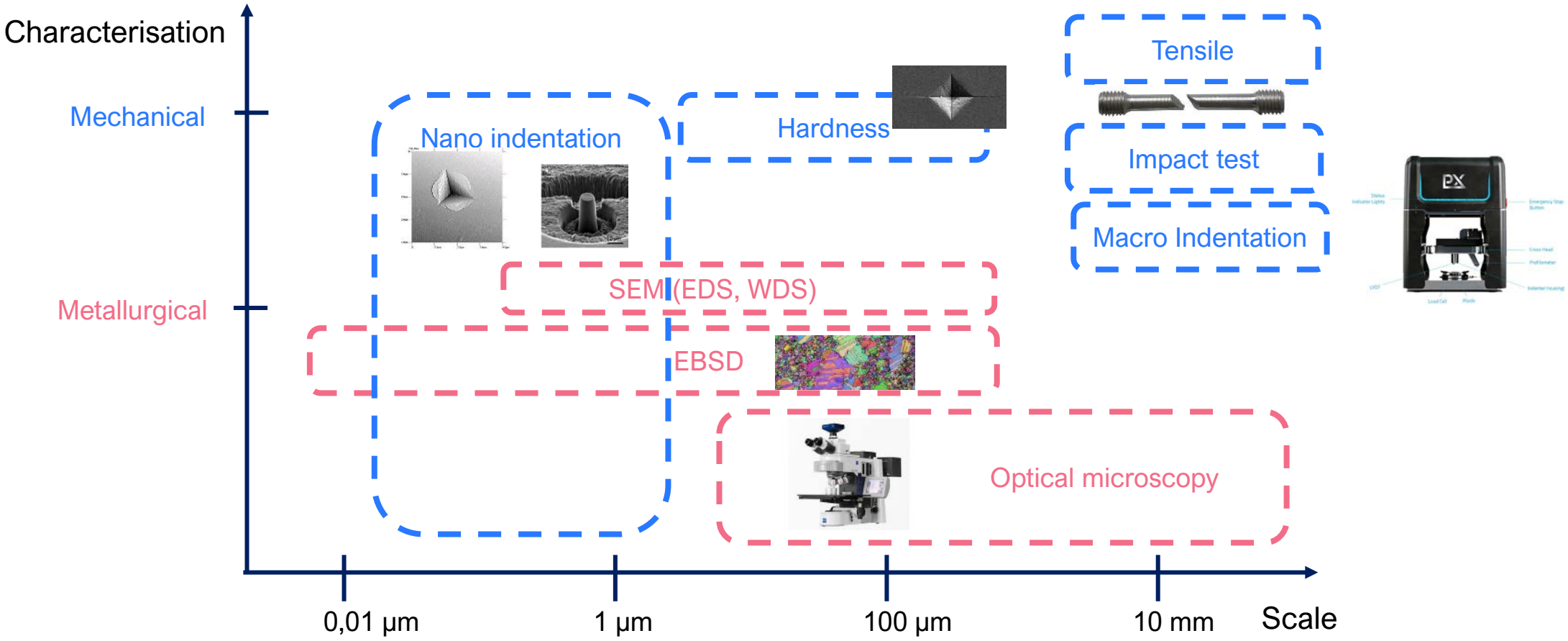
Mechanical testing under H_2 environment



- **Environment: H_2, N_2, He, CH_4 and blends**
- **Temperature: from 20K to 700K**
- **In addition, pressure vessel for static ageing/uptaking until 350°C & 1000 bars**

Multi-scale material Characterization

Mechanical & Metallurgical



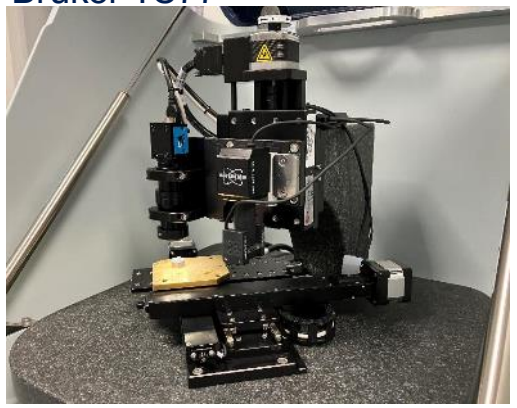
Multi-scale material Characterization

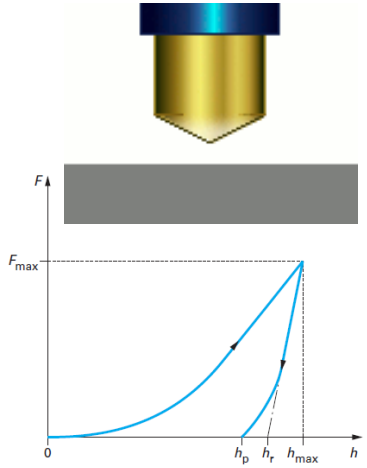
Nano indentation – equipment and R&D project

2 devices : standalone and SEM in-situ

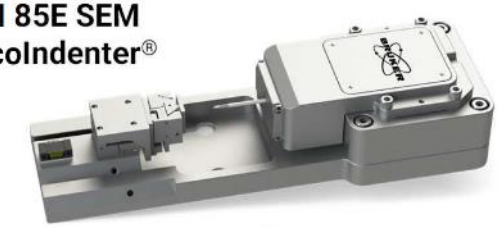
- Local mechanical characterisation
  - Hardness (nano and micro scale)
  - Young's modulus
  - Behaviour laws (micro-pillar)
- Surfaces characterisation
- Analysis of metallurgical phases or powder grains
- Nano-scale hardness **mapping**
- Studies on a wide range of materials, including composites/thin films

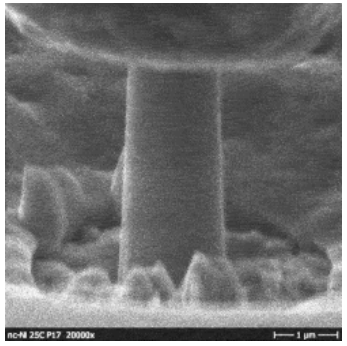
Bruker TS77





PI 85E SEM PicoIndenter®





Physico-chemical analysis / characterization

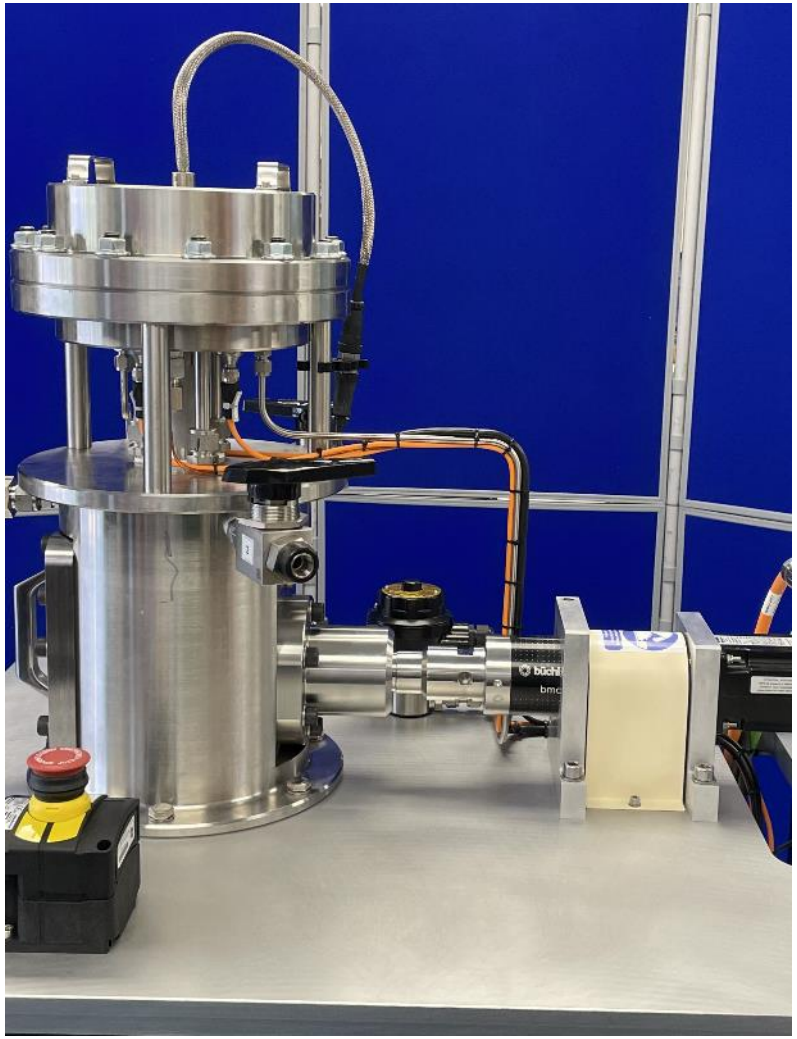
H_2 Quantification in Metallic Materials

- Thermo-desorption spectroscopy

Permeation

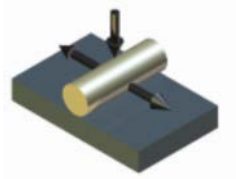
- Electro-chemical permeation
- Gaseous permeation
  - Temperature: up to 200°C
  - Pression: up to 400 bar

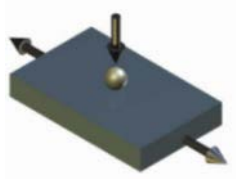
High-Pressure H_2 tribometer

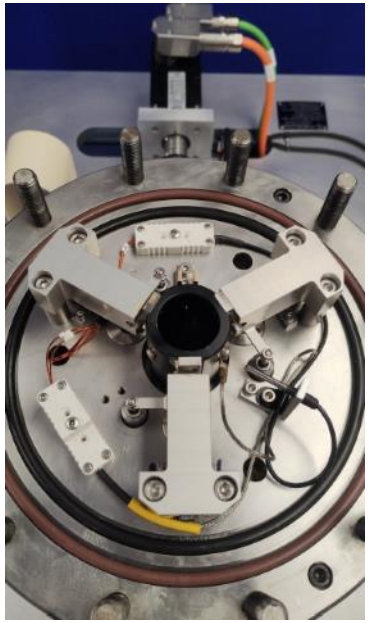


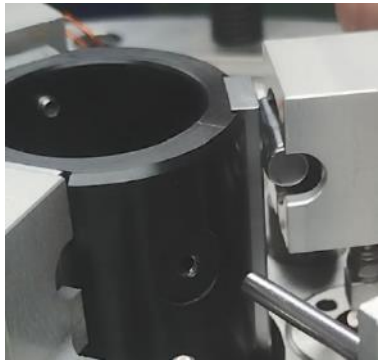
Reciprocating Tribometer

- **3 Workstations**
- **Max Pressure: 80 bar**
- **Operating Conditions**
  - Stroke: 0 to 20 mm
  - Frequency: 0 to 5 Hz
  - Normal Load: 5 to 50 N
  - Temperature: -55 to 150°C









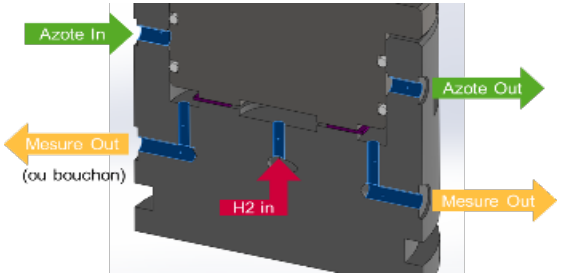
Sealing performances

Fugitive emissions & Leakage

- **Bolted flange connections**

Ageing @80°C

2000 kN load capacity, up to 200 bar



Test cell for sealing tests & mechanical tests on flat gaskets

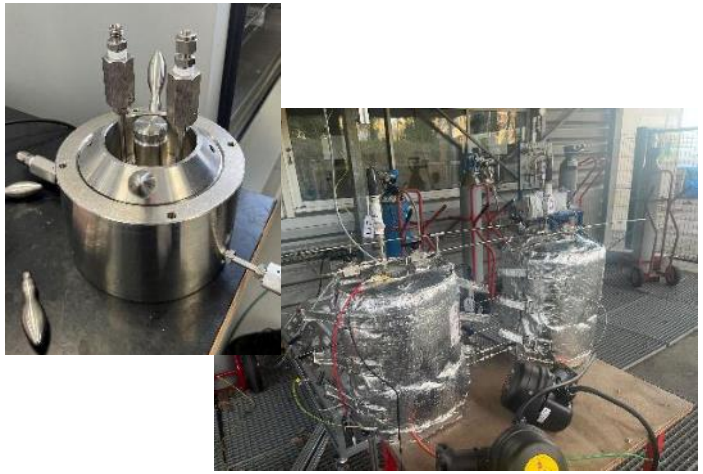
- **Components characterization**
  - **Definition of acceptable leakage rates**
  - **Leakage monitoring**

@ Vallourec VAM® connections

Sealing performances

Fugitive emissions & Leakage

- **Rapid gas decompression 1000bar & 70bar/min**
- **Material ageing**
- **Permeation tests & fugitive emissions**
- **Leakage monitoring**



Permeation

Ageing

H_2 rapid gas decompression

ATEX Lab for H_2

Deep cryogenic testing facilities

Deployement of dedicated equipements

- **Rapid gas decompression 1000bar & 70bar/min**
- **Thermo Mecanical Analysis down to 4K**

Cryogenic TMA

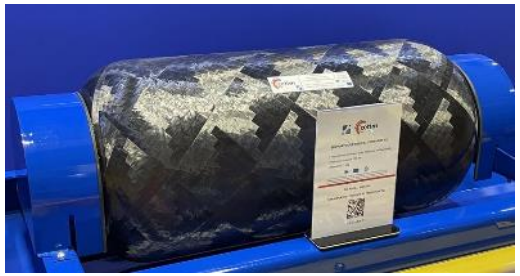
- **Deep Cryo Management**
  - Liquefier He / H_2 100 L / day
  - Associated Cryostats
- **Instruction Dynamic seals in LH_2**
- **Instruction flow rate testing needs**

Liquefier & cryostat in LH_2 configuration

Material / design/ process: HySPIDE TP®

HySPIDE TP® (Laser Assisted Tape Placement / Winding):

- **New fully automated pilot line dedicated to CTP tank manufacturing**
- **In-situ TP consolidation with last generation and unique optimized head**
- **Benefits : Quality, repeatability and reliability, ↗ tolerance to damage, ↘ cost & Reduction of the environmental footprint**

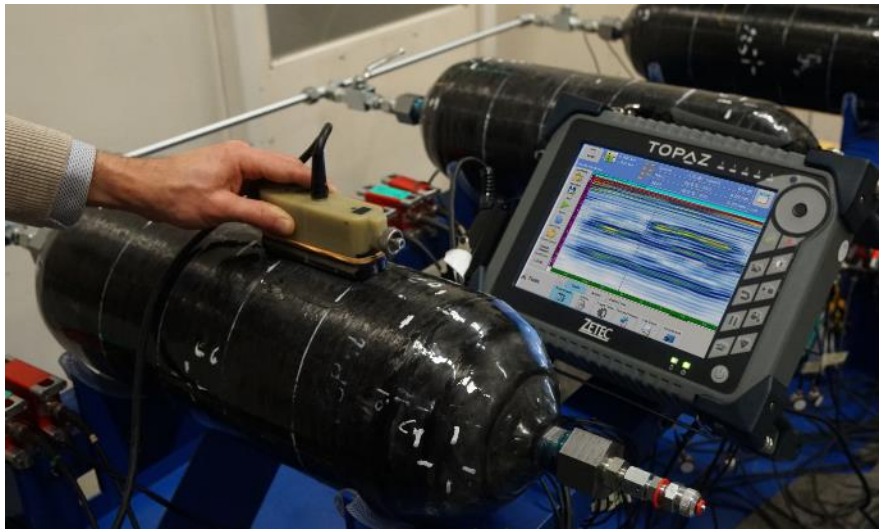


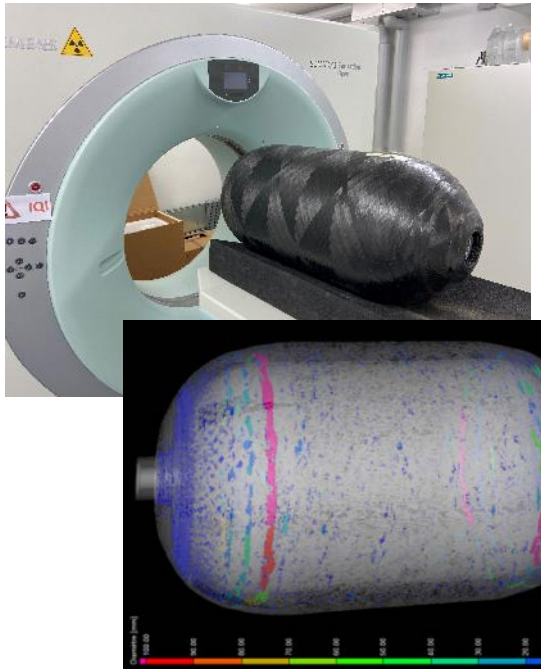
Réservoir Cetim de type IV-b
(Projet EU THOR)

Control & Monitoring: Tanks monitoring

H_2 type IV tanks control & monitoring:

- NDT testing
- Testing & monitoring at scale 1
- Suppport in damage understanding

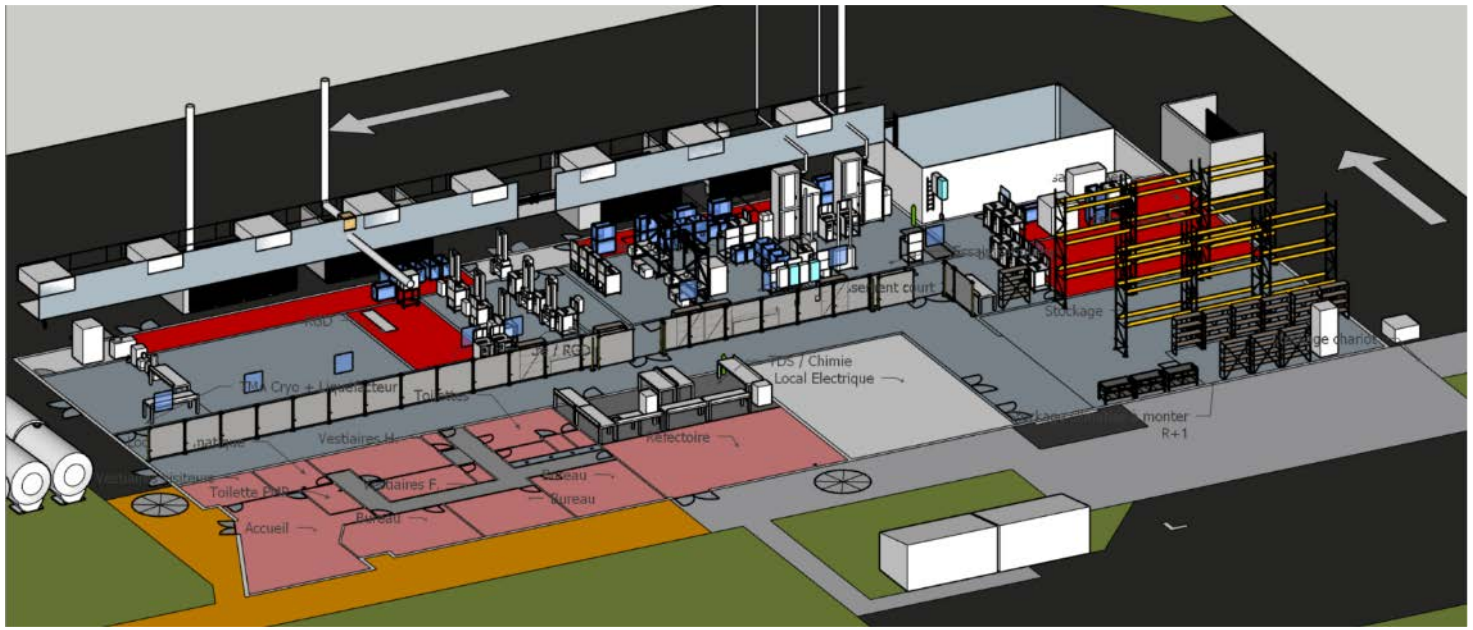




Dedicated H_2 testing plateform

Hymeet tests plateform dedicated to H_2

- 1850m² in Nantes
- 4th Quater 2024



CETIM

Pour un futur industriel responsable et respectueux de la planète

Multi-scale material Characterization

4 laboratories

- **Tensile tests** (NF EN ISO 6892-1 ou ATSM E8M)
  - Capacity: 150kN, 300kN, 600kN.
  - Temperature range: -185°C to 1200°C
- **Hardness and microhardness** (NF EN ISO 6506, 6507, 6508)
  Rockwell, Brinell, Vickers
- **Impact test** (NF EN ISO 148-1)

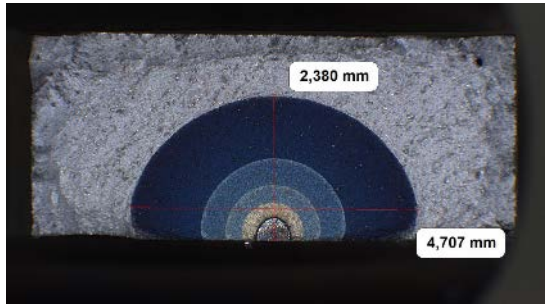
  Down to -196°C
  Possible at high temperature
  Determination of ductile/brittle transition curves
- **Flexion, Compression, Shear**
- **Instrumented mechanical testing** (strain gauges)
- **Determination of behaviour laws**
  - Voce $\sigma = \sigma 0 \cdot (1 - e^{-A\varepsilon})$
  - Hollomon $\sigma = k \cdot \varepsilon n$

Mechanical testing at Cetim

Example of mechanical tests at RVE scale

- Constitutive behavior of materials
  - Monotoneous : tensile test on a large range of strain rate (from 10^{-6} s^{-1} to 10^{-1} s^{-1}), relaxation tests, creep tests …
  - Cyclic : cyclic hardening tests with or w/o dwell time under iso and anisothermal conditions (100-900°C)
- Strengh of materials
  - Toughness : K, J, CTOD, R-Curve
  - Force or strain controlled fatigue test under iso and anisothermal conditions
  - Fatigue crack growth & threshold tests under various configurations
- Testing facility located at Senlis, Saint Etienne and Nantes (*dedicated to severe gaseous env.*)
- Temperature & environment
  - In air: from -185°C to 950°C
  - In liquid env. : NaCl, Simili-blood
  - In gazeous env.
  - Lot of measurement techniques used to support strain (global/local) and crack advance (DPCD, COD) monitoring

Crack propagation from EDM notch on KBR specimen monitor by DPCD techniques



Front crack markings for DPCD calibration

With courtesy of Safran aircraft engine