



**Hydrogen
Capability
Network**



HENRY
ROYCE
INSTITUTE



UK Cryogenic & Hydrogen Materials Testing Landscape

March 2025



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About

This work was carried out by the **Aerospace Technology Institute's Hydrogen Capability Network**, with support from the **National Physical Laboratory (NPL)**, the **Henry Royce Institute** and the **Hydrogen Innovation Initiative (HII)**.

This report is at its second revision, to include information that was highlighted about additional capability with Element Materials Technology.

About the Aerospace Technology Institute

The **Aerospace Technology Institute (ATI)** is an independent organisation that works alongside government and industry to transform UK aerospace through technology and innovation. The ATI is funded equally by the **Department for Business and Trade (DBT)** and by industrial recipients of project grants who pay a small levy. ATI projects are chosen and overseen through close collaboration with Innovate UK and DBT.

As well as running this portfolio of R&T projects, the ATI conducts strategic research projects to help define and answer systemic questions of value to the UK aerospace sector. In 2022 the ATI published the findings of the **FlyZero** project, which concluded that liquid hydrogen is the most viable zero-carbon emission fuel with the potential to scale to larger aircraft.

The ATI Programme has made several investments in liquid hydrogen technologies to support the next generation of zero-carbon aircraft. The **Hydrogen Capability Network (HCN)** was launched in April 2023 funded by the Department for Business and Trade, to progress key recommendations from FlyZero which will enable the aerospace sector to deliver liquid hydrogen research & development (R&D).

Disclaimer

The report is based on our understanding of facilities that can conduct testing either: in a cryogenic environment at 77K or below, or in an environment of gaseous hydrogen, or using in-situ electrochemical charging, available or under commissioning as of March 2025. Although every effort has been made to ensure it reflects a comprehensive view of the UK landscape, there could be capability that was not shared or is not in the public domain. The ATI does not accept liability for any errors, omissions or misleading statements and no warranty is given or responsibility accepted for any actions users may take based on the content of the report. The ATI reserves the right at any time to make changes to the material, or discontinue the report, without notice.

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Introduction

The Aerospace Technology Institute’s (ATI) FlyZero project developed roadmaps covering the technologies needed for liquid hydrogen (LH2) flight to be viable¹. These covered topics that are both generic (such as automation, digital twins and materials) and specific (such as aerodynamic modifications to manage dry wings, fuel cell development and gas turbine hydrogen combustion).

Building on FlyZero recommendations the ATI’s Hydrogen Capability Network (HCN), through engagement with key stakeholders across academia and industry, has identified that the UK has strong existing knowledge and research capability in many of the topics required to deliver an aircraft capable of liquid-hydrogen-powered flight. There is, however, a clear exception with on-aircraft cryogenic hydrogen fuel storage and distribution systems.

The challenge relates specifically to the storage and distribution of hydrogen fuel between the fuel tank and propulsion source, across a wide range of fluid temperatures and pressures. A high-level overview of technologies and components used in a liquid hydrogen fuel system can be seen in Figure 1, as developed during an ATI Hub Innovation Showcase event².

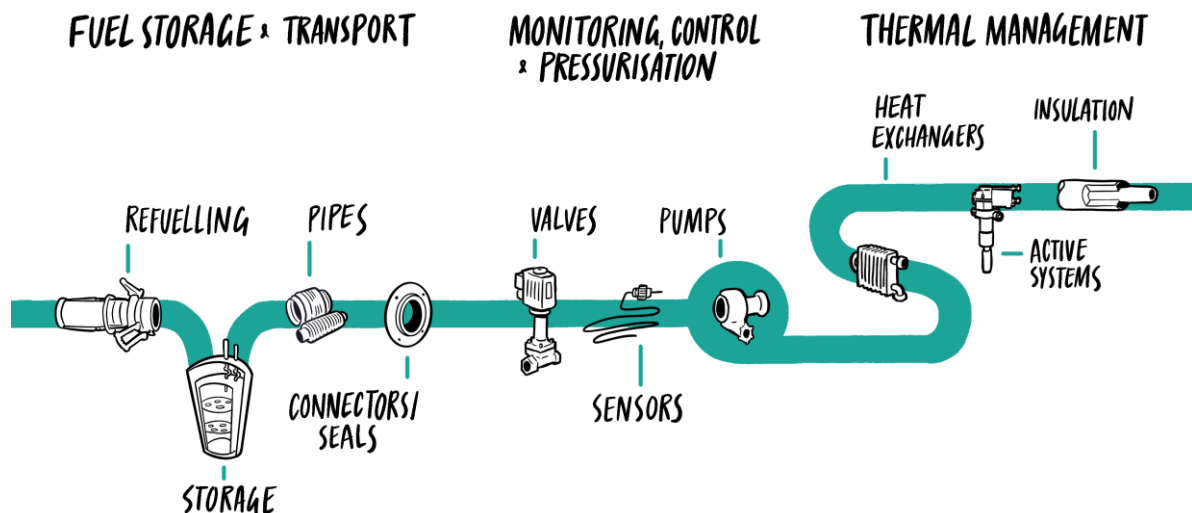


Figure 1 : Schematic providing a high-level overview of technologies and components across a liquid hydrogen fuel system

Supporting the ecosystem to accelerate the development of fundamental knowledge will enhance the UK’s ability to contribute to the development of these technologies and therefore zero carbon aircraft. This aligns directly with both Government’s Net Zero policy objectives and the objectives of the HCN. During the first 12 months of the HCN, the following underpinning research topics were identified as requiring particular focus to enable technology development:

- **Materials:** Fundamental material behaviour at cryogenic temperatures and hydrogen environments
- **Thermofluids:** Cryogenic hydrogen thermofluids behaviour
- **Health & Safety:** Cryogenic hydrogen health and safety protocols, modelling, and testing

¹ [FlyZero Reports Archive - Aerospace Technology Institute \(ati.org.uk\)](https://ati.org.uk/flyzero-reports-archive)

² [ATI Hub – The ATI Hub is a space for innovators to connect, access expertise and collaborate.](https://ati.org.uk/hub)

The HCN is working to develop research proposals to address these topics, aligned to key research gaps and industrial priorities, as evaluated through international landscaping activities and workshops with industrial members.

To support researchers who would like to investigate the impact of hydrogen and cryogenic environments on materials, this report captures UK based, hydrogen and cryogenic materials testing capability. Specifically, this report highlights cryogenic test capability and only includes test capability with cryogenic (≤ 77 K) or hydrogen test environments. Test capability suited to the evaluation of metallics, polymers and composites are included, as evaluation of candidate materials across the LH2 fuel system currently includes austenitic stainless steels, aluminium based and nickel-based alloys, composite materials and sealant materials.

This report produced in collaboration between the HCN, the Hydrogen Innovation Initiative (HII), the National Physical Laboratory (NPL) and the Henry Royce Institute, serves an update to the report previously published by the Henry Royce Institute, "*Royce Hydrogen Blueprints*"³. This activity has partially been completed during the development of the Cryogenic Hydrogen Materials Testing Standards (CHYMES) programme, which is working to develop standardised material test methods for the tests discussed in this report.

³ [UK-Hydrogen-Testing-Blueprint-1.2.pdf](#)

UK Cryogenic and Hydrogen Materials Testing Landscape Overview

This report summarises the cryogenic and hydrogen materials testing capabilities across UK - based commercial and research organisations. This covers test facilities for the evaluation of mechanical, thermal, hydrogen transport and other properties typically used to understand materials behaviour for design and certification purposes.

In order to highlight test capabilities that can further our fundamental understanding of materials behaviour in cryogenic and hydrogen environments, this document only considers facilities that can conduct testing either: in a cryogenic environment at 77 K or below, or in an environment of gaseous hydrogen, or using in-situ electrochemical charging.

This report should therefore not be used as an exhaustive list of all capabilities at these organisations but may be used to understand capabilities under these test conditions.

The following UK based organisations have materials testing capability that meet these criteria:

- | | |
|--|---|
| 1. University of Bath | 11. National Physical Laboratory |
| 2. University of Birmingham | 12. University of Oxford |
| 3. University of Bristol | 13. University of Southampton |
| 4. Composite Test & Evaluation Ltd | 14. Science and Technology Facilities Council |
| 5. Cranfield University | |
| 6. Darvick | 15. University of Strathclyde |
| 7. Element Materials Technology | 16. UK Atomic Energy Authority |
| 8. Hive Composites | 17. The Welding Institute |
| 9. University of Manchester | 18. Warwick Manufacturing Group |
| 10. National Composites Centre | |

All capabilities captured are open access and are believed to be correct at the time of publishing. Test capability was submitted to the HCN by the individual organisations listed using a standardised data template. Planned future capabilities are not included for clarity. A Point of Contact (POC) for technical enquiries from each organisation is also listed.

The following observations may be made about the current state of play of UK cryogenic and hydrogen materials testing capability, with the findings illustrated in Figure 2:

- **Mechanical Testing:** There is extremely limited capacity for mechanical testing of materials in cryogenic hydrogen test environments. Cryogenic mechanical behaviour of materials below 77 K may be evaluated at few sites of limited capacity.
- **Transport Testing:** Hydrogen transport within materials is evaluated at multiple locations and there has been work to benchmark these, including under liquid hydrogen conditions.
- **Thermal Testing:** Inert-atmosphere, cryogenic thermophysical property testing is available at multiple sites, however there is no capability to conduct testing in a hydrogen environment, apart from thermal shock testing at one site.
- **Other Testing:** There are a very limited number of micro/nano-scale test capabilities for non-destructive evaluation in cryogenic or hydrogen environments and limited specialised testing for the evaluation of tribology or other phenomena related effects.

UK Cryogenic and Hydrogen Materials Testing Landscape

The following UK organisations have the capability to test materials under the following environment conditions:

Cryogenic hydrogen ≤20 K ≤77 K **Cryogenic inert** ≤20 K ≤77 K **In-situ hydrogen** **Not available**

- | | |
|------------------------------------|---|
| 1. University of Bath | 11. National Physical Laboratory |
| 2. University of Birmingham | 12. University of Oxford |
| 3. University of Bristol | 13. University of Southampton |
| 4. Composite Test & Evaluation Ltd | 14. Science and Technology Facilities Council |
| 5. Cranfield University | 15. University of Strathclyde |
| 6. Darvick | 16. UK Atomic Energy Authority |
| 7. Element Materials Technology | 17. The Welding Institute |
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| 9. University of Manchester | |
| 10. National Composites Centre | |

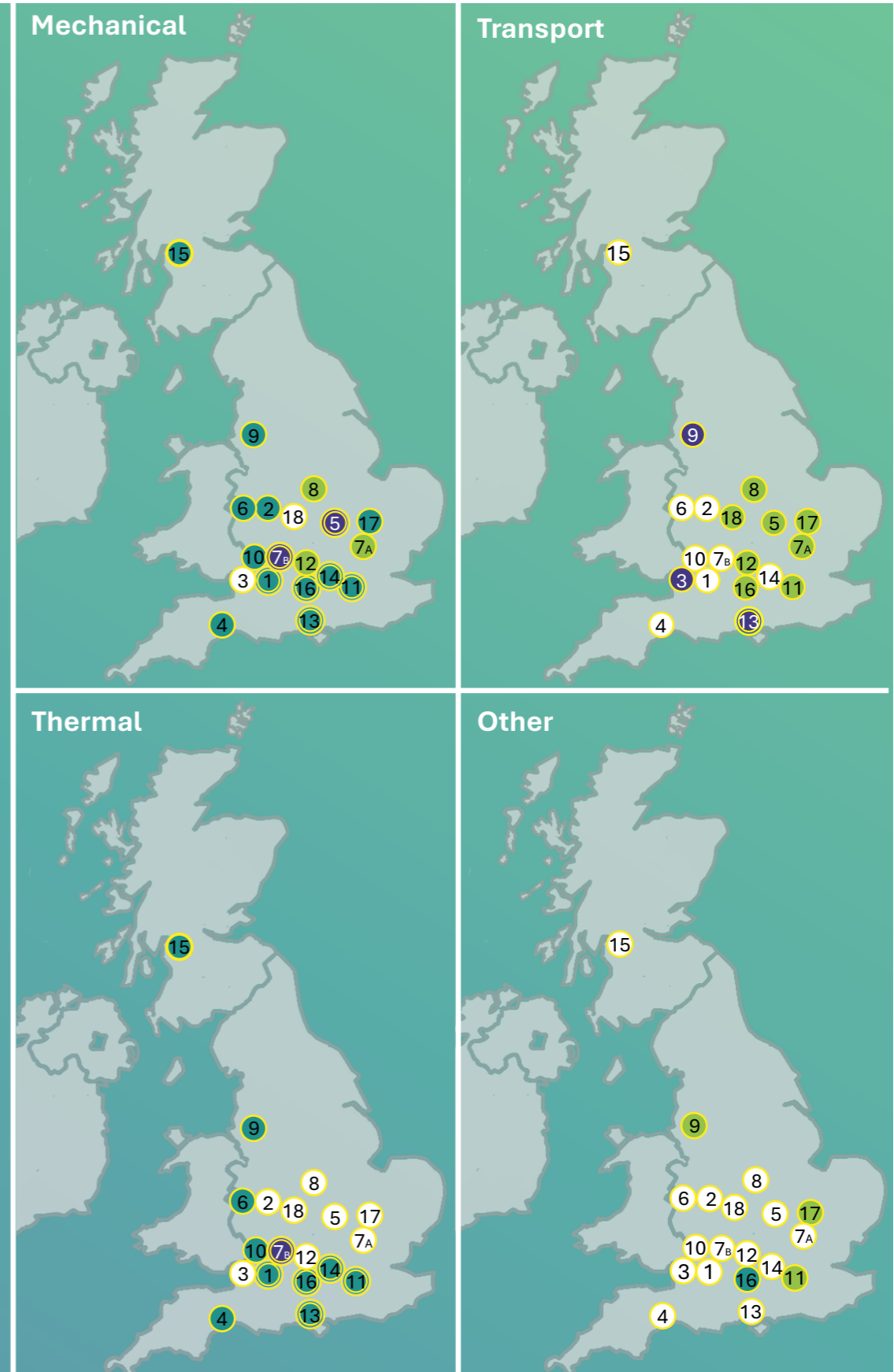


Figure 2: UK Cryogenic and Hydrogen Materials Testing Landscape

Conclusion

Knowledge of fundamental materials behaviour in cryogenic hydrogen environments is a key enabler for the development of liquid hydrogen technologies. This fundamental understanding is required early in the development phase of liquid hydrogen powered aircraft, with demand for material test capability expected to grow. The UK's capability to test materials in cryogenic and hydrogen environments is currently found in a small number of organisations, primarily in academic institutions, where capacity to conduct test programmes is limited. The variety of testing available is not universal across these organisations. An expansion of test capability will be required to not only address missing capability with respect to testing environments, but also to provide UK based capacity for future material evaluation programmes.

However, capability is evolving rapidly, with many organisations developing more capability than currently listed across the variety of tests. This momentum is being supported by a number of on-going programmes, including the work at the ATI to develop standardised materials test methods (CHYMES⁴), and wider infrastructure development for the supply of liquid hydrogen in quantities suitable for research.

The Henry Royce Institute recently published recommendations under the National Materials Innovation Strategy⁵. The strategy focuses effort on the largest opportunities for impact. One of six theme areas, Energy Solutions highlighted the opportunities in materials for hydrogen storage, transport and end use, calling for research and development programmes to focus on the UK's essential needs for energy, transport, aerospace, cryogenics and more specific defence requirements.

The Henry Royce Institute is also supporting investment in cryogenic test capability. Under the theme of Materials for Demanding Environments, Cranfield University was awarded a grant for a fatigue rig for cryogenic, high-pressure hydrogen testing, and the capability is currently in development.

NPL has been working in the clean hydrogen sector for over two decades and as of 2024 has approximately 30 experts from across multiple scientific disciplines working to develop the necessary measurement techniques, protocols, modelling tools and standards. Over that period, NPL's work in hydrogen has focused on supporting the development of fuel cells and electrolyzers, providing reliable gas quality measurements, assessing the suitability of existing gas infrastructure, and developing new test capabilities to support deployment of hydrogen transportation and storage infrastructure. In response to identified measurement challenges as highlighted in the *Energy transition: Measurement needs within the hydrogen industry* report⁶, NPL has invested in developing capability for measuring the performance of advanced materials at cryogenic hydrogen temperatures to better support the development of emerging liquid hydrogen applications.

The Hydrogen Innovation Initiative (HII) also aims to continue its support of cross-sector collaboration and knowledge sharing for materials research and support the development of critical infrastructure to enable the hydrogen economy in its next phase operation.

⁴ <https://www.ati.org.uk/wp-content/uploads/2023/11/Materials-Standards-Intervention-Final-Slides.pdf>

⁵ <https://www.royce.ac.uk/collaborate/innovationstrategy/>

⁶ <https://www.npl.co.uk/resources/energy-transition/hydrogen-report-2024>

Appendix – Detailed Capability per Organisation

1. University of Bath

University of Bath		Material Type			Environment hardware			Environmental parameters			Mechanical parameters			Brief description of equipment	
Link		Metallics	Composites	Polymers	Environmental Chamber	Atmosphere	Hollow specimen compatible	Temperature (K)		Pressure (bar)	Temp. rate (K min ⁻¹)	Load capacity (kN)	Frequency (Hz)		
								Minimum	Maximum	Maximum	Maximum	Maximum	Maximum		Minimum
POC	Dr Andrew Rhead; atr21@bath.ac.uk				Cryostat	Vacuum	Y	20	300	1		300			
Mechanical	Quasi-static tension	Y	Y	Y	Cryostat	Vacuum	Y	20	300	1		300		Vacuum based cryostat on Instron 8803 hydraulic fatigue system. Optical access. 100 kN and 650 kN (static)/500 kN (fatigue) load cells. Cryostat currently designed for 300 kN.	
	Slow strain rate	Y	Y	Y	Cryostat	Vacuum	Y	20	300	1		300			
	Low cycle fatigue	Y	Y	Y	Cryostat	Vacuum	Y	20	300	1		300			
	Fracture toughness	Y	Y	Y	Cryostat	Vacuum		20	300	1		300			
	Impact	Y	Y	Y	Cryostat	Helium		20	300	1		Energy (J)	50	Split Hopkinson Pressure Bar with gaseous helium and cold head based cooling. Plans for cryostat conversion from mechanical test to drop weight.	
	Interlaminar shear		Y		Cryostat	Vacuum		20	300	1					

University of Bath		Material Type			Environment hardware			Environmental parameters				Mechanical parameters			Brief description of equipment
Link		Metallics	Composites	Polymers	Environmental Chamber	Atmosphere	Hollow specimen compatible	Temperature (K)		Pressure (bar)	Temp. rate (K min ⁻¹)	Load capacity (kN)	Frequency (Hz)		
								Minimum	Maximum				Maximum	Maximum	
POC	Dr Andrew Rhead; atr21@bath.ac.uk														
Thermal	Thermal conductivity	Y	Y	Y				20	300						
								20	300						
	Thermal cycling	Y	Y	Y	Cryostat	Vacuum		20	300	1					
	Thermal shock	Y	Y	Y	Cryostat	Vacuum		20	300	1					

2. University of Birmingham

University of Birmingham		Material Type			Environment hardware			Environmental parameters			Mechanical parameters			Brief description of equipment	
Link	https://www.birmingham.ac.uk/research/energy/research/centre-energy-storage	Metallics	Composites	Polymers	Environmental Chamber	Atmosphere	Hollow specimen compatible	Temperature (K)		Pressure (bar)	Temp. rate (K min ⁻¹)	Load capacity (kN)	Frequency (Hz)		
								Minimum	Maximum				Maximum		Maximum
POC	Prof. Yulong Ding; y.ding@bham.ac.uk														
Mechanical	Quasi-static tension	Y	Y	N	None	Air	N	50	700			100			

3. University of Bristol

University of Bristol		Material Type			Environment hardware			Environmental parameters			Mechanical parameters			Brief description of equipment	
Link		Metallics	Composites	Polymers	Environmental Chamber	Atmosphere	Hollow specimen compatible	Temperature (K)		Pressure (bar)	Temp. rate (K min ⁻¹)	Load capacity (kN)	Frequency (Hz)		
								Minimum	Maximum	Maximum	Maximum	Maximum	Minimum		
POC	Dr. Lui Skytree; lt7006@bristol.ac.uk														
Transport	Permeation, diffusivity	Y	Y	Y	Wet bath or gas change	Hydrogen		77	323	80					<p>Use the accumulation method to determine permeability (pressure sensor based).</p> <p>CHyPr I - Holds 25-30mm disc or square samples. Future ambitions: CHyPr 2, samples will be ~100mm disc and pressure up to 100 bar, and CHyPr 3, complete with a cryostat system capable of full temperature control from 20 to 300 K.</p>

4. Composite Test & Evaluation

Composite Test & Evaluation		Material Type			Environment hardware			Environmental parameters			Mechanical parameters			Brief description of equipment	
Link	www.compositetest.com	Metallics	Composites	Polymers	Environmental Chamber	Atmosphere	Hollow specimen compatible	Temperature (K)		Pressure (bar)	Temp. rate (K min ⁻¹)	Load capacity (kN)	Frequency (Hz)		
								Minimum	Maximum				Maximum		Maximum
POC	contact@compositetest.com														
Mechanical	Quasi-static tension	Y	Y	Y	Wet bath or gas change	Air		77	473	77		250		Using pre-immersion in LN2	
	Slow strain rate	Y	Y	Y	Wet bath or gas change	Air		77	473	77		250			
	Low cycle fatigue	Y	Y	Y	None	Air		300	300	300		250			
	High cycle fatigue	Y	Y	Y	None	Air		300	300	300		250			
	Fracture toughness	Y	Y	Y	Wet bath or gas change	Air		77	473	77		250		Using pre-immersion in LN2	
	Interlaminar shear		Y		Wet bath or gas change	Air		77	473	77		250			
Thermal	Thermal shock	Y	Y	Y	Wet bath or gas change			77	573					Switching between LN2 immersion and Hot Oven with manual transfer	

5. Cranfield University

Cranfield University		Material Type			Environment hardware			Environmental parameters			Mechanical parameters			Brief description of equipment	
Link	https://www.cranfield.ac.uk/	Metallics	Composites	Polymers	Environmental Chamber	Atmosphere	Hollow specimen compatible	Temperature (K)		Pressure (bar)	Temp. rate (K min ⁻¹)	Load capacity (kN)	Frequency (Hz)		
								Minimum	Maximum				Maximum		Maximum
POC	Dr. Francesco Fanicchia; francesco.fanicchia@cranfield.ac.uk														
Mechanical	Quasi-static tension	Y	Y	Y	Wet bath or gas change	Hydrogen	Y	20	1200	1		100		LH2 rig 100kN, other rigs 50kN. LH2 20-300K. GH2(1bar) 300-1200K. Pre-charged hydrogen 77-1200K. Polymer limited on stroke (100mm full scale). (Max frequency dependent on stroke requirement)	
	Slow strain rate	Y	Y	Y	Wet bath or gas change	Hydrogen	Y	20	1200	1		100			
	Low cycle fatigue	Y	Y	Y	Wet bath or gas change	Hydrogen	Y	20	1200	1		100	100		
	High cycle fatigue	Y	Y	Y	Wet bath or gas change	Hydrogen	Y	20	1200	1		100	100		
	Fracture toughness	Y	N	N	Wet bath or gas change	Hydrogen		20	1200	1		100			PD crack growth requires conducting specimens. LH2 20-300K. GH2(1bar) 300-1200K. Pre-charged hydrogen 77-1200K. Polymer limited on stroke (100mm full scale). LH2 rig 100kN, other rigs 50kN

Cranfield University		Material Type			Environment hardware			Environmental parameters				Mechanical parameters			Brief description of equipment
Link	https://www.cranfield.ac.uk/	Metallics	Composites	Polymers	Environmental Chamber	Atmosphere	Hollow specimen compatible	Temperature (K)		Pressure (bar)	Temp. rate (K min ⁻¹)	Load capacity (kN)	Frequency (Hz)		
								Minimum	Maximum	Maximum	Maximum	Maximum	Minimum		
POC	Dr. Francesco Fanicchia; francesco.fanicchia@cranfield.ac.uk														
Transport	Permeation, diffusivity	Y	Y	Y	Pressure vessel	Hydrogen		300	1100	150					
Thermal	Thermal cycling	Y	Y	Y	Wet bath or gas change	H ₂ O, O ₂ , N ₂ , Ar, etc.		300	1500	1	10				Several thermal cycling rigs working in different, controllable, atmospheres. Cooling rates up to 1000°C/min by direct water jet spray.
	Thermal shock	Y	Y	Y	Wet bath or gas change	H ₂ O, O ₂ , N ₂ , Ar, etc.		300	1500	1	10				

6. Darvick

Darvick		Material Type			Environment hardware			Environmental parameters				Mechanical parameters			Brief description of equipment
Link	www.darvick.co.uk	Metallics	Composites	Polymers	Environmental Chamber	Atmosphere	Hollow specimen compatible	Temperature (K)		Pressure (bar)	Temp. rate (K min ⁻¹)	Load capacity (kN)	Frequency (Hz)		
								Minimum	Maximum	Maximum	Maximum	Maximum	Minimum		
Mechanical	Quasi-static tension	Y	Y	Y	Pressure vessel	Hydrogen	Y	300	300	300				0.0001	UKAS accredited up to 1000°C, can heat up to 2000°C
	Slow strain rate	Y	Y	Y	Pressure vessel	Hydrogen	Y	300	300	300					Lowest strain rate 5 x 10 ⁻⁶
	High cycle fatigue	Y	Y	Y	Pressure vessel	Hydrogen	Y	300	300	300					
	Fracture toughness	Y	Y	Y	Pressure vessel	Hydrogen		300	300	300					
Thermal	Thermal cycling	Y	Y	Y	Pressure vessel	Hydrogen		77	1000	100	100			Can go through 0°C on a thermal cycle	

7. Element Materials Technology (UK)

Element Materials Technology (A - Hitchin)		Material Type			Environment hardware			Environmental parameters			Mechanical parameters			Brief description of equipment	
Link	www.element.com	Metallics	Composites	Polymers	Environmental Chamber	Atmosphere	Hollow specimen compatible	Temperature (K)		Pressure (bar)	Temp. rate (K min ⁻¹)	Load capacity (kN)	Frequency (Hz)		
								Minimum	Maximum	Maximum	Maximum	Maximum	Maximum		Minimum
Mechanical	Quasi-static tension	Y			Pressure vessel	Hydrogen		300	300	300		100			ASTM G142. Also available in-situ electrochemical charging to AMPP/Nace TM0198 In-situ electrochemical charging also available ASTM E1820 / EPRG Guidelines. In-situ electrochemical charging available
	Slow strain rate	Y			Pressure vessel	Hydrogen		300	300	300		100			
	High cycle fatigue	Y			Pressure vessel	Hydrogen		300	300	300		100		0.0001	
	Fracture toughness	Y			Pressure vessel	Hydrogen		300	300	300		100			
Transport	Permeation, diffusivity		Y		Pressure vessel			240	480	300					

Element Materials Technology (B - Kemble)		Material Type			Environment hardware			Environmental parameters				Mechanical parameters			Brief description of equipment
Link	www.element.com	Metallics	Composites	Polymers	Environmental Chamber	Atmosphere	Hollow specimen compatible	Temperature (K)		Pressure (bar)	Temp. rate (K min ⁻¹)	Load capacity (kN)	Frequency (Hz)		
								Minimum	Maximum	Maximum	Maximum	Maximum	Maximum	Minimum	
POC	Dr Mark Eldridge; mark.eldridge@element.com	Y			Cryostat	Hydrogen	N	20	300	100		100			
					Cryostat	Hydrogen	N	20	300	100		100	5	1	
Mechanical	Slow strain rate	Y								1		Energy (J)			
	Impact	Y				Helium				1					
Thermal	Thermal cycling	Y	Y					20	300						
	Thermal shock	Y	Y	Y	Cryostat	Hydrogen		20	300						

8. Hive Composites

Hive Composites		Material Type			Environment hardware			Environmental parameters			Mechanical parameters			Brief description of equipment	
Link	www.hivecomposites.com	Metallics	Composites	Polymers	Environmental Chamber	Atmosphere	Hollow specimen compatible	Temperature (K)		Pressure (bar)	Temp. rate (K min ⁻¹)	Load capacity (kN)	Frequency (Hz)		
								Minimum	Maximum	Maximum	Maximum	Maximum	Maximum		Minimum
POC	Peter Hansen; p.hansen@hivecomposites.com														
Mechanical	Quasi-static tension	N	Y	Y	Pressure vessel	Hydrogen	Y	300	360	100		150		Offline exposure in H2 pressure vessels, subsequent testing on Zwick 150kN test machine with test cabinet up to 200C. Offline exposure cabinet down to -85°C. Can also perform H2 RGD tests.	
	Slow strain rate	N	Y	Y	Pressure vessel	Hydrogen		300	360	100		150			
	Low cycle fatigue	N	Y	Y	Pressure vessel	Hydrogen	Y	300	360	100		150			
	Impact	N	Y	Y	Pressure vessel	Hydrogen		300	360	100			Energy (J)	100	Offline exposure in H2 pressure vessels, subsequent testing on Charpy or drop-weight impact frame
	Interlaminar shear		Y		Pressure vessel	Hydrogen		300	360	100			150		

Hive Composites		Material Type			Environment hardware			Environmental parameters			Mechanical parameters			Brief description of equipment	
Link	www.hivecomposites.com	Metallics	Composites	Polymers	Environmental Chamber	Atmosphere	Hollow specimen compatible	Temperature (K)		Pressure (bar)	Temp. rate (K min ⁻¹)	Load capacity (kN)	Frequency (Hz)		
								Minimum	Maximum				Maximum		Minimum
POC	Peter Hansen; p.hansen@hivecomposites.com														
Transport	Permeation, diffusivity		Y	Y	Pressure vessel	Hydrogen		300	360	100					

9. University of Manchester

University of Manchester		Material Type			Environment hardware			Environmental parameters			Mechanical parameters			Brief description of equipment		
Link		Metallics	Composites	Polymers	Environmental Chamber	Atmosphere	Hollow specimen compatible	Temperature (K)		Pressure (bar)	Temp. rate (K min ⁻¹)	Load capacity (kN)	Frequency (Hz)			
	POC							royce@manchester.ac.uk	Minimum	Maximum	Maximum	Maximum	Maximum		Maximum	Minimum
Mechanical	Quasi-static tension	Y	Y	Y	Immersion	LN2	N	77	300	1		100			Also available at up to 300 bar from room temperature to 300°C	
	Slow strain rate	Y	Y	Y	Immersion	LN2	N	77	300	1		100				
	Low cycle fatigue	Y	Y	Y	Immersion	LN2	N	77	300	1		100	20	0.1		
	High cycle fatigue	Y	Y	Y		Ar	N	300	1300	1		100	20	1		
	Fracture toughness	Y	Y	Y	Immersion	LN2		77	300	1		100				Also available at up to 300 bar from room temperature to 300°C
	Impact	Y	Y	Y	Pre-immersion	LN2		77	300	1						

University of Manchester		Material Type			Environment hardware			Environmental parameters				Mechanical parameters			Brief description of equipment
Link		Metallics	Composites	Polymers	Environmental Chamber	Atmosphere	Hollow specimen compatible	Temperature (K)		Pressure (bar)	Temp. rate (K min ⁻¹)	Load capacity (kN)	Frequency (Hz)		
	POC							royce@manchester.ac.uk	Minimum	Maximum	Maximum	Maximum	Maximum	Maximum	
Transport	Permeation, diffusivity	Y	Y	Y	Pressure vessel	Hydrogen		300	300	100					
	<i>Thermal desorption spectroscopy</i>	Y	Y	Y	Cryostat	Hydrogen		200	1273	1					
Thermal	Specific heat capacity	Y	Y	Y		<i>Metallic</i>		300	1300						
						<i>Non-metallic</i>		300	1300						
	Thermal expansion	Y	N	N		<i>Metallic</i>		100	1300						
						<i>Non-metallic</i>									
Thermal cycling	Y	Y	Y				77	453	1	10					
Other	Mechanical testing with in-situ imaging	Y	Y	Y		Vacuum		100	1073	1					

10. National Composites Centre

National Composites Centre		Material Type			Environment hardware			Environmental parameters			Mechanical parameters			Brief description of equipment	
Link	https://www.nccuk.com/	Metallics	Composites	Polymers	Environmental Chamber	Atmosphere	Hollow specimen compatible	Temperature (K)		Pressure (bar)	Temp. rate (K min ⁻¹)	Load capacity (kN)	Frequency (Hz)		
								Minimum	Maximum				Maximum		Maximum
POC	hydrogen@nccuk.com														
Mechanical	Quasi-static tension	N	Y	Y	Wet bath or gas change	Air	N	77	330	1				The NCC's 3D printed cryo chambers are used with cryogenic nitrogen gas dispensers to chill the specimens	
	Low cycle fatigue	N	Y	Y	Wet bath or gas change	Air	N	77	330	1					
	High cycle fatigue	N	Y	Y	Wet bath or gas change	Air	N	77	330	1					
	Interlaminar shear		Y		Wet bath or gas change	Air									
Thermal	Thermal cycling	N	Y	Y	Wet bath or gas change	Liquid Nitrogen		77	330	1					
	Thermal shock	N	Y	Y	Wet bath or gas change	Liquid Nitrogen		77	330	1					

11. National Physical Laboratory

NPL		Material Type			Environment hardware			Environmental parameters			Mechanical parameters			Brief description of equipment	
Link	https://www.npl.co.uk	Metallics	Composites	Polymers	Environmental Chamber	Atmosphere	Hollow specimen compatible	Temperature (K)		Pressure (bar)	Temp. rate (K min ⁻¹)	Load capacity (kN)	Frequency (Hz)		
								Minimum	Maximum	Maximum			Maximum		Minimum
POC	Dr Stefanos Giannis; stefanos.giannis@npl.co.uk														
Mechanical	Quasi-static tension	Y	Y	Y	Cryostat	Helium	N	20	300	1		100			
	Slow strain rate	Y	Y	Y	Pressure vessel	Hydrogen	N	277	473	200		50			Min strain rate is 10 ⁻⁷ s ⁻¹
	Low cycle fatigue	Y	Y	Y	Cryostat	Helium	N	20	300	1		100	20	0.1	
	High cycle fatigue	Y	Y	Y	Cryostat	Helium	N	20	300	1		100	20	1	
	Fracture toughness	Y	Y	Y	Cryostat	Helium		20	300	1		100			
	Micro-, Nano-mechanical testing	Y	Y	Y		Vacuum		77	1073	1		0.0005			
	Interlaminar shear		Y		Cryostat	Helium		20	300	1		100			

NPL		Material Type			Environment hardware			Environmental parameters				Mechanical parameters			Brief description of equipment
Link	https://www.npl.co.uk	Metallics	Composites	Polymers	Environmental Chamber	Atmosphere	Hollow specimen compatible	Temperature (K)		Pressure (bar)	Temp. rate (K min ⁻¹)	Load capacity (kN)	Frequency (Hz)		
								Minimum	Maximum	Maximum	Maximum	Maximum	Minimum		
POC	Dr Stefanos Giannis; stefanos.giannis@npl.co.uk														
Transport	Permeation, diffusivity	Y	Y	Y	Pressure vessel	Hydrogen		300	300	100					
	Thermal desorption spectroscopy	Y	Y	Y	Pressure vessel	Hydrogen		300	1173	200					
Thermal	Thermal conductivity	Y	Y	Y		<i>Metallic</i>		4	1670						
						<i>Non-metallic</i>		153	1670						
	Thermal Diffusivity	Y	Y	Y		<i>Metallic</i>		4	1848						
						<i>Non-metallic</i>		153	1848						
	Specific heat capacity	Y	Y	Y		<i>Metallic</i>		4	1773						
						<i>Non-metallic</i>		93	1773						
	Thermal expansion	Y	Y	Y		<i>Metallic</i>		4	1773						
						<i>Non-metallic</i>		123	1773						
Thermal cycling	Y	Y	Y	Wet bath or gas change	Helium		77	453	1	10					
Thermal shock	Y	Y	Y	Wet bath or gas change	Helium		203	573	1	40					

NPL		Material Type			Environment hardware			Environmental parameters				Mechanical parameters		Brief description of equipment	
Link	https://www.npl.co.uk	Metallics	Composites	Polymers	Environmental Chamber	Atmosphere	Hollow specimen compatible	Temperature (K)		Pressure (bar)	Temp. rate (K min ⁻¹)	Load capacity (kN)	Frequency (Hz)		
								Minimum	Maximum	Maximum	Maximum	Maximum	Minimum		
POC	Dr Stefanos Giannis; stefanos.giannis@npl.co.uk														
Other	Static charging	Y	Y	Y	Pressure vessel	Hydrogen	N	277	473	200					

12. University of Oxford

University of Oxford		Material Type			Environment hardware			Environmental parameters			Mechanical parameters			Brief description of equipment	
Link	https://mechmat.web.ox.ac.uk/	Metallics	Composites	Polymers	Environmental Chamber	Atmosphere	Hollow specimen compatible	Temperature (K)		Pressure (bar)	Temp. rate (K min ⁻¹)	Load capacity (kN)	Frequency (Hz)		
								Minimum	Maximum	Maximum	Maximum	Maximum	Minimum		
POC	emilio.martinez-paneda@eng.ox.ac.uk														
Mechanical	Quasi-static tension	Y	Y	Y	Wet bath or gas change	In-situ Electro-chemical	Y	300	300	1		75			
	Slow strain rate	Y	Y	Y	Wet bath or gas change	In-situ Electro-chemical	Y	300	300	1		75			
	Low cycle fatigue	Y	Y	Y	Wet bath or gas change	In-situ Electro-chemical	Y	300	300	1		75			
	High cycle fatigue	Y	Y	Y	Wet bath or gas change	In-situ Electro-chemical	Y	300	300	1		75			
	Fracture toughness	Y	Y	Y	Wet bath or gas change	In-situ Electro-chemical		300	300	1		75			

University of Oxford		Material Type			Environment hardware			Environmental parameters			Mechanical parameters			Brief description of equipment	
Link	https://mechmat.web.ox.ac.uk/	Metallics	Composites	Polymers	Environmental Chamber	Atmosphere	Hollow specimen compatible	Temperature (K)		Pressure (bar)	Temp. rate (K min ⁻¹)	Load capacity (kN)	Frequency (Hz)		
								Minimum	Maximum	Maximum	Maximum	Maximum	Maximum		Minimum
POC	emilio.martinez-paneda@eng.ox.ac.uk														
Transport	Permeation, diffusivity	Y	Y	Y	Wet bath or gas change	Hydrogen		300	520	15					
	Thermal desorption spectroscopy	Y	Y	Y				300	1273						

13. University of Southampton

University of Southampton		Material Type			Environment hardware			Environmental parameters			Mechanical parameters			Brief description of equipment			
Link	https://www.southampton.ac.uk/engineering/research/groups/energy_technology/institute_of_cryogenics.page	Metallics	Composites	Polymers	Environmental Chamber	Atmosphere	Hollow specimen compatible	Temperature (K)		Pressure (bar)	Temp. rate (K min ⁻¹)	Load capacity (kN)	Frequency (Hz)				
								Minimum	Maximum	Maximum	Maximum	Maximum	Minimum				
POC	Dr Wendell Bailey ; wosb@soton.ac.uk																
Mechanical	Quasi-static tension	Y	Y	Y	Cryostat	Helium	N	20	300	1	50	50		Lower limit of strain rate is from $8.33 \times 10^{-8} \text{ s}^{-1}$ to $3 \times 10^{-7} \text{ s}^{-1}$ for composites, polymers and metallic samples (depends on their length)			
	Slow strain rate	Y	Y	Y	Cryostat	Helium	N	20	300	1							
	Low cycle fatigue	Y	Y	Y	Cryostat	Nitrogen	Y	110	300	1					300		
	Fracture toughness	Y	Y	Y	Cryostat	Helium		20	300	1					50		
	Impact	Y	Y	Y	Cryostat	Nitrogen/ Helium		50	373	1					Energy (J)	200	
	Interlaminar shear		Y		Cryostat	Helium		20	300	1					50		

University of Southampton		Material Type			Environment hardware			Environmental parameters				Mechanical parameters			Brief description of equipment
Link	https://www.southampton.ac.uk/engineering/research/groups/energy_technology/institute_of_cryogenics.page	Metallics	Composites	Polymers	Environmental Chamber	Atmosphere	Hollow specimen compatible	Temperature (K)		Pressure (bar)	Temp. rate (K min ⁻¹)	Load capacity (kN)	Frequency (Hz)		
								Minimum	Maximum	Maximum	Maximum	Maximum	Maximum	Minimum	
Transpor	Permeation, diffusivity	Y	Y	Y	Pressure vessel	Hydrogen/ Helium		20	300	2					
Thermal	Thermal conductivity	Y	Y	Y		<i>Metallic</i>		4	300						PPMS in Helium
				<i>Non-metallic</i>		4	300								
	Thermal Diffusivity	Y	Y	Y		<i>Metallic</i>	4	300							
				<i>Non-metallic</i>		4	300								
	Specific heat capacity	Y	Y	Y		<i>Metallic</i>	4	300							
				<i>Non-metallic</i>		4	300								
	Thermal expansion	Y	Y	Y		<i>Metallic</i>	4	373							
				<i>Non-metallic</i>		4	373								
Thermal	Thermal cycling	Y	Y	Y				20	373	1	2				
	Thermal shock	Y	Y	Y				77	373	1	40				
Oth	Tribology & Wear	Y	Y	Y	Cryostat	Nitrogen		110	373	1					

14. Science and Technology Facilities Council

STFC		Material Type			Environment hardware			Environmental parameters			Mechanical parameters			Brief description of equipment	
Link	https://www.isis.stfc.ac.uk/Pages/engine-x.aspx	Metallics	Composites	Polymers	Environmental Chamber	Atmosphere	Hollow specimen compatible	Temperature (K)		Pressure (bar)	Temp. rate (K min ⁻¹)	Load capacity (kN)	Frequency (Hz)		
								Minimum	Maximum	Maximum	Maximum	Maximum	Maximum		Minimum
POC	ISIS: tung-lik.lee@stfc.ac.uk; TD: graham.appleby@stfc.ac.uk	Y	Y	N	Cryostat	Vacuum	N	7	500	1		100			Available at ISIS
								4	500	1		100			
Mechanical	Quasi-static tension	Y	Y	N	Cryostat	Vacuum	N	7	500	1		100	0	20	Available at ISIS (down to 7K) & Technology Department (down to 77K)
	Slow strain rate	Y	Y	N	Cryostat	Vacuum	N	4	500	1		100	0	20	Available at ISIS (down to 7K) & Technology Department (down to 77K)
	Low cycle fatigue	Y	Y	N	Cryostat	Vacuum	N	7	500	1		100	0	20	Available at ISIS (down to 7K) & Technology Department (down to 77K)
	High cycle fatigue	Y	Y	N	Cryostat	Vacuum	N	7	500	1		100	0	20	Available at ISIS (down to 7K) & Technology Department (down to 77K)
	Fracture toughness	Y	Y	N	Cryostat	Vacuum		7	500	1		100			Available at ISIS

STFC		Material Type			Environment hardware			Environmental parameters			Mechanical parameters			Brief description of equipment	
Link	https://www.isis.stfc.ac.uk/Pages/engine-x.aspx	Metallics	Composites	Polymers	Environmental Chamber	Atmosphere	Hollow specimen compatible	Temperature (K)		Pressure (bar)	Temp. rate (K min ⁻¹)	Load capacity (kN)	Frequency (Hz)		
	Minimum							Maximum	Maximum				Maximum		Maximum
POC	ISIS: tunglik.lee@stfc.ac.uk; TD: graham.appleby@stfc.ac.uk														
Thermal	Thermal expansion	Y	Y	N		<i>Metallic</i>	4	500						Available at ISIS (down to 7K) & Technology Department (down to 4K)	
						<i>Non-metallic</i>	4	500						Available at ISIS - Maximum cooling ramp rate is 0.03 K s ⁻¹ . Maximum heating ramp rate is 9 K s ⁻¹	
	Thermal cycling	Y	Y	N	Cryostat	Vacuum		7	500	1					
	Thermal shock	N	N	N	Wet bath or gas change	Nitrogen		77						Available at the Technology Department facility	

15. University of Strathclyde

University of Strathclyde		Material Type			Environment hardware			Environmental parameters			Mechanical parameters			Brief description of equipment	
Link	Advanced Materials Research Laboratory; https://cryogenicpropulsion.com/our-team/professor-min-zhang/	Metallics	Composites	Polymers	Environmental Chamber	Atmosphere	Hollow specimen compatible	Temperature (K)		Pressure (bar)	Temp. rate (K min ⁻¹)	Load capacity (kN)	Frequency (Hz)		
								Minimum	Maximum				Maximum		Maximum
POC	fiona.sillars@strath.ac.uk; min.zhang@strath.ac.uk														
Mechanical	Quasi-static tension	Y	N	N	Wet bath or gas change	In-situ Electro-chemical	N	280	300	1		100			Instron 8801 with in-house developed electrochemical charging set-up, therefore only conductive materials possible
	Low cycle fatigue	Y	N	N	Wet bath or gas change	In-situ Electro-chemical	N	280	300	1			15	1	
	High cycle fatigue	Y	N	N	Wet bath or gas change	In-situ Electro-chemical	N	280	300	1			15	1	
	Fracture toughness	Y	N	N	Wet bath or gas change	In-situ Electro-chemical		280	300	1					
	Impact	Y	Y	Y	Wet bath or gas change	Air		77	333	1					
Transport	Permeation, diffusivity	Y	N	N	Wet bath or gas change	Hydrogen									

University of Strathclyde		Material Type			Environment hardware			Environmental parameters			Mechanical parameters		Brief description of equipment		
Link	Advanced Materials Research Laboratory; https://cryogenicpropulsion.com/our-team/professor-min-zhang/	Metallics	Composites	Polymers	Environmental Chamber	Atmosphere	Hollow specimen compatible	Temperature (K)		Pressure (bar)	Temp. rate (K min ⁻¹)	Load capacity (kN)		Frequency (Hz)	
								Minimum	Maximum	Maximum	Maximum	Maximum		Maximum	Minimum
POC	fiona.sillars@strath.ac.uk; min.zhang@strath.ac.uk														
Thermal	Thermal shock	Y	Y	Y	Wet bath or gas change	Nitrogen		77							

16. UK Atomic Energy Authority

UK Atomic Energy Authority		Material Type			Environment hardware			Environmental parameters				Mechanical parameters			Brief description of equipment	
Link	https://ccfe.ukaea.uk/divisions/fusion-technology/applied-materials-technology/	Metallics	Composites	Polymers	Environmental Chamber	Atmosphere	Hollow specimen compatible	Temperature (K)		Pressure (bar)	Temp. rate (K min ⁻¹)	Load capacity (kN)	Frequency (Hz)			
								Minimum	Maximum	Maximum			Maximum	Minimum		
POC	Glyn.Stanton@ukaea.uk															
Mechanical	Quasi-static tension	Y	Y	Y	Cryostat	Helium	Y	20	1273	1		100				
	Slow strain rate	Y	Y	Y	Cryostat	Helium	Y	20	1273	1		100				
	Low cycle fatigue	Y	Y	Y	Cryostat	Helium	Y	20	1273	1		100			20	0.1
	High cycle fatigue	Y	Y	Y	Cryostat	Helium		20	30	1		100			20	1
	Fracture toughness	Y	Y	Y	Cryostat	Helium		20	1273	1		100				
	Micro-, Nano-mechanical testing	Y	Y	Y	Vacuum			77	300	1		0.0005				
	Interlaminar shear		Y		Cryostat	Helium		20	300	1		100				

UK Atomic Energy Authority		Material Type			Environment hardware			Environmental parameters				Mechanical parameters			Brief description of equipment
Link	https://ccfe.ukaea.uk/divisions/fusion-technology/applied-materials-technology/	Metallics	Composites	Polymers	Environmental Chamber	Atmosphere	Hollow specimen compatible	Temperature (K)		Pressure (bar)	Temp. rate (K min ⁻¹)	Load capacity (kN)	Frequency (Hz)		
								Minimum	Maximum				Maximum	Maximum	
POC	Glyn.Stanton@ukaea.uk														
Transport	Permeation, diffusivity	Y	Y	Y	Pressure vessel	Hydrogen		300	300	100					
Thermal	Thermal conductivity	Y	Y	Y		<i>Metallic</i>	4	1670							UKAEA PPMS can perform measurements of sample thermal conductivity, resistivity, Seebeck coefficient and thermoelectric figure of merit
						<i>Non-metallic</i>	153	1670							
	Thermal Diffusivity	Y	Y	Y		<i>Metallic</i>	4	1848							
						<i>Non-metallic</i>	153	1848							
	Specific heat capacity	Y	Y	Y		<i>Metallic</i>	4	1773							
						<i>Non-metallic</i>	93	1773							
	Thermal expansion	Y	Y	Y		<i>Metallic</i>	4	1773							
						<i>Non-metallic</i>	123	1773							
															Dilatometer

UK Atomic Energy Authority		Material Type			Environment hardware			Environmental parameters				Mechanical parameters			Brief description of equipment	
Link	https://ccfe.ukaea.uk/divisions/fusion-technology/applied-materials-technology/	Metallics	Composites	Polymers	Environmental Chamber	Atmosphere	Hollow specimen compatible	Temperature (K)		Pressure (bar)	Temp. rate (K min ⁻¹)	Load capacity (kN)	Frequency (Hz)			
								Minimum	Maximum				Maximum	Maximum		Minimum
POC	Glyn.Stanton@ukaea.uk															
	Thermal cycling	Y	Y	Y	Wet bath or gas change			77	453	1	10					
	Thermal shock	Y	Y	Y				203	573	1	40					
Other	Nano-Indentation	Y	Y	Y		Vacuum		123	1279					UKAEA MRF – In-situ nano indenter with cryo (-150C) and high temperature (1000C) modules as well as ambient temperature rotation and tilt stage. Radioactive sample compatible (limits apply)		
	Ga FIB-SEM	Y	Y	Y		Vacuum		123	300					UKAEA MRF - Ga FIB with cryo stage (-150C) for low temperature FIB operation. Radioactive sample compatible (limits apply)		

17. The Welding Institute

TWI		Material Type			Environment hardware			Environmental parameters				Mechanical parameters			Brief description of equipment
Link	https://www.twi-global.com/contact	Metallics	Composites	Polymers	Environmental Chamber	Atmosphere	Hollow specimen compatible	Temperature (K)		Pressure (bar)	Temp. rate (K min ⁻¹)	Load capacity (kN)	Frequency (Hz)		
								Minimum	Maximum	Maximum	Maximum	Maximum	Minimum		
POC	michael.dodge@twi.co.uk														
Mechanical	Quasi-static tension	Y	Y	Y	Pressure vessel	Hydrogen	N	290	353	450		100		Various servo-hydraulic load frames and pressure vessels. Can be upgraded to 200kN. When testing at 150 Bar we can do -40°C at a max of 25kN	
	Slow strain rate	Y	Y	Y	Pressure vessel	Hydrogen	N	290	353	450		100		Can be upgraded to 200kN. Strain rate depends on specimen size. Lower rate circa 10 ⁻⁷ /s typical	
	High cycle fatigue	Y	Y	Y	Pressure vessel	Hydrogen	N	290	353	450		100	3	0.0001	Various servo-hydraulic load frames and pressure vessels.
	Fracture toughness	Y	Y	Y	Pressure vessel	Hydrogen		290	353	450		100			Various servo-hydraulic load frames and pressure vessels. Can be upgraded to 200kN

TWI		Material Type			Environment hardware			Environmental parameters				Mechanical parameters			Brief description of equipment
Link	https://www.twi-global.com/contact	Metallics	Composites	Polymers	Environmental Chamber	Atmosphere	Hollow specimen compatible	Temperature (K)		Pressure (bar)	Temp. rate (K min ⁻¹)	Load capacity (kN)	Frequency (Hz)		
								Minimum	Maximum	Maximum	Maximum	Maximum	Maximum	Minimum	
POC	michael.dodge@twi.co.uk														
	Impact	Y	Y	Y		Air		77	573	1		Energy (J)			Sheen drop-weight impact tester, Pellini, Charpy
Transport	Permeation, diffusivity	Y	Y	Y	Pressure vessel	Hydrogen		295	423	250					High pressure permeation cell, capable of testing with various gases. Electrochemical permeation (D-S cell) also available at ambient pressure.
	Thermal desorption spectroscopy	Y	N	N				300	1373	1					Bruker Galileo G8 with Mass Spectrometer, post hydrogen charging
Other	Static charging	Y	Y	Y	Pressure vessel	Hydrogen		300	800	100					In-house designed and built thermal hydrogen pre-charging autoclave. Can be used for static loading experiments (i.e. bolt-loaded specimens)

18. Warwick Manufacturing Group

WMG		Material Type			Environment hardware			Environmental parameters			Mechanical parameters			Brief description of equipment	
Link	https://warwick.ac.uk/fac/sci/wmg/	Metallics	Composites	Polymers	Environmental Chamber	Atmosphere	Hollow specimen compatible	Temperature (K)		Pressure (bar)	Temp. rate (K min ⁻¹)	Load capacity (kN)	Frequency (Hz)		
								Minimum	Maximum				Maximum		Maximum
POC	l.w.fiegel@warwick.ac.uk														
Transport	Permeation, diffusivity	N	Y	Y	Pressure vessel	Hydrogen		273	333	200					