H2FC

European Infrastucture Project

Integrating European Infrastructure to support science and development of Hydrogen-and Fuel Cell Technologies towards European Strategy for Sustainable, Competitive and Secure Energy

EXPERIMENTAL INSTALLATIONS BOOK

H2FC European Infrastructure is an Integrating Activity funded by the European Commission under FP7 Capacities Programme
Grant Agreement no. FP7-284522

** ENEA installations: no actual provisions till month 24*

H_2FC

European Infrastucture Project

H2FC is **your gateway** to unique portfolio of fuel cells and hydrogen investigation technologies.

- 15 access providers
- access to 49 installations
- ~ 60 internal experts
- Around 180 user projects envisaged

Your advantage

- No fee open access on scientific excellence is available for applicants from industry or research institutions located in EU member states and associated states
- Proposals will be evaluated by an experienced peer review board
- Proprietary project upon request

Your benefits

- Benefit from efficient test facilities in fuel cells and hydrogen investigation technologies
- Experience hands-on access or services on emerging needs
- EC financial support for the costs of the use of installations, technological expertise and advice, travel and living expenses of users

Access to H2FC installations is granted by online application submission through the H2FC entry point

www.h2fc.eu

Kick-off meeting, Karlsruhe, 18-20 January 2012

H_2FC

European Infrastucture Project

Technologies Portfolio and Expertise

The consortium capability covers the entire life cycle of hydrogen technologies and fuel cells, from material issues in bipolar plates, electrodes, catalysts, electrolytes, piping and pressure vessels, hydrogen production, through storage, distribution and finally to power conversion in fuel cells or combustions engines. Research on cross-cutting issues, in particular hazards, risks and safety, is perfectly accommodated in the consortium's facilities, which have been proven to be worldwide leading, in particular with regard to hydrogen release and combustion analysis as well as sensor evaluation and calibration. The consortium has a unique position concerning the development and in particular the evaluation of solid storage materials, which need further research for approaching market entry. Other outstanding capabilities and capacities with respect to cross-cutting items concern the software tools and educational training infrastructures.

Hydrogen Production and Storage

Synthesis of hydrogen storage materials
Structuring (also nano) of hydrogen storage materials
Powder neutron diffractometer
Small angle neutron scattering
Solid-state hydrogen storage testing facility
High-pressure hydrogen tank testing facility
Synthesis of hydrogen storage materials
Characterisation of hydrogen storage materials

Fuel Cells

SOFC tests
Performance and durability Infrastructure
Environmental test chamber
ICON beam line mobile fuel cell test bench / multicell setup
Fuel Cell Laboratory
2.5 kWe / 300W/ 3 W / 16 W SOFC test bech; 11 W / 300 Kwe MCFC test bench
Small and wide angle x-ray diffractometers
Neutron CRG low spectrometer angle Brillouin
Hydrogen assisted stress cracking
Instrumented PEMFC test station
Electrochemical techniques for characterization of catalyst performance
Gas chromatography for hydrogen purity
Membrane and materials research laboratory
PEM durability diagnostics lab

Safety Issues

Hydrogen Safety Issues
Safety and risk assessments
High pressure hydrogen facility
Tunnel / enclosure facility
Impact facilities
Fire testing rig for tanks and other pressure vessels
Air test site for open air large scale tests with fire
Tribmeters for oscillating or sliding friction

INSTALLATIONS

HYDROGEN PRODUCTION AND STORAGE

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Germany	KIT	MH syn	maximilian.fichtner@kit.edu
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Germany	KIT	HYKA-A8 Facility	mike.kuznetsov@kit.edu
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Name of the organization
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Name of the infrastructure / laboratory
MHsyn

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Main field of activity of the infrastructure / laboratory
- *Hydrogen Storage*

Short description of the infrastructure / laboratory
A metal organic laboratory is available to synthesize air sensitive compounds by chemical methods. High temperature synthesis can be performed in specially designed autoclaves. Separation procedures for clean-up of products and desolvation are established, all for working under strictly inert conditions. For mechanical synthesis, high energy ball mills are available. Reactive milling under pressures up to 150 bar is possible. All synthesis procedures are accompanied by state-of-the art characterization methods in order to guarantee chemical purity, microstructure, and H storage capabilities of the product. The above mentioned techniques allow synthesis of new and state-of- the art materials. One additional possibility is to synthesize the hydride in isotope-labelled form which is necessary for sophisticated characterization methods using neutrons, for example.

Main research area(s) of the infrastructure / laboratory
A variety of synthesis methods in a unique combination of chemical and mechanical techniques. In particular, the above mentioned techniques allow synthesis of new and state-of-the art materials. One additional possibility is to synthesize the hydride in isotope-labelled form which is necessary for sophisticated characterization methods using neutrons, for example.

Instruments and tools available for the above mentioned research
A metal organic laboratory with 4 lab hoods which are fully equipped with Schlenk lines, 5 high energy ball mills with milling vials from 80 ml to 20 L and a big and powerful high energy vibration mill (SIEBTECHNIK GmbH) with rotational speed up to 1200 rpm is installed in a tailormade glove box in order to synthesize and handle large amounts of hydride material under strictly inert conditions. Thus, 1-2 kg nanocompositic hydride material can be produced per batch.

High energy ball mills

High energy vibration mill

Name of the organization
Karlsruhe Institute of Technology (KIT)

Name of the infrastructure / laboratory
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Main field of activity of the infrastructure / laboratory
- *Hydrogen Storage*

Short description of the infrastructure / laboratory
The laboratory facilities for solid storage materials include state-of-the art and sophisticated instrumentation that allows accurate H2 storage measurements at different pressure/ temperature conditions with a unique combination of chemical, volumetric, gravimetric and calorimetric analysis techniques.

Main research area(s) of the infrastructure / laboratory
Investigation of hydrogen storage materials

Instruments and tools available for the above mentioned research
Chemical composition can be analyzed by an Elemental Analyzer (CE Instruments). For H storage properties 3 specially designed PCT volumetric systems are available (0-150 bar, 300-700 K), a NETZSCH STA 409C Thermal Analyzer for combined TGA-DTA-MS experiments, a SETARAM Thermal Analyzer for combined TGA-DSC-MS measurements and DSC experiments under reactive atmosphere up to 300 bar, a NETZSCH Phoenix high pressure DSC for high pressure calorimetry. Structural characterization is possible with a BRUKER Advance D8 X-ray diffractometer, Moessbauer spectrometry (Fe, Sn), a Perkin-Elmer Spectrum GX FTIR spectrometer, a Perkin-Elmer Laser Raman spectrometer, several SEM microscopes (LEO Gemini) with EDX option and an ultra-high resolution transmission electron microscope (FEI Titan CS 80-300) with FIB as a possibility for sample preparation.

HP-DSC

Physi-/Chemisorption apparatus

Powder X-ray diffractometer

Name of the organization
Karlsruher Institut für Technologie (KIT)

Name of the infrastructure / laboratory
HYKA-HyJet (a High Pressure Hydrogen Jet Release)

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Dr. Mike KUZNETSOV

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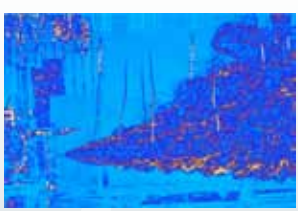
Main field of activity of the infrastructure / laboratory
- *Hydrogen safety, hydrogen storages, refueling*

Short description of the infrastructure / laboratory
Different high pressure vessels with a volume from 0.2 to 12 dm3 at initial pressure up to 700 bar can be investigated with respect to high pressure hydrogen releases through different nozzles. The facility was used to study hydrogen releases from pressurized vessel, dynamic hydrogen concentrations and flow velocity profiles, investigations self-ignition of hydrogen and flammability of the turbulent hydrogen jet at different pressures from several bar to 700 bar. The facility is equipped with measuring ports for pressure transducers and a schlieren system for visual observations. The measuring system consists of thermocouples array (gas temperature), piezoelectric and piezoresistive gauges (bulk pressure, local pressure), gas analyzer and mass spectrometer (to control mixture composition), ultrasonic detector for hydrogen concentrations and PIV technique as well. The data acquisition system is based on multi-channel (64) ADC with a sampling rate of 1 MHz.

Main research area(s) of the infrastructure / laboratory
Hydrogen jet combustion, high pressure hydrogen releases, hydrogen distribution, self-ignition limits for hydrogen jets

Instruments and tools available for the above mentioned research
Gas filling system, high speed imaging (up to 200000 fr.p.s.) combined with BOS or/and PIV technique



Name of the organization
Karlsruher Institut für Technologie (KIT)

Name of the infrastructure / laboratory
HYKA-A8 Facility (a High Pressure Test Vessel)

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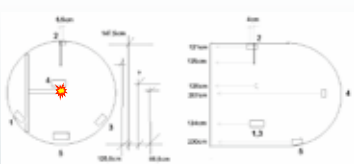
Main field of activity of the infrastructure / laboratory
- *Hydrogen safety, refueling, hydrogen storages*

Short description of the infrastructure / laboratory
The safety vessel A8 has main dimensions of 1.8 m id and 3.7 m length with a volume of 8.8 m3. It was certified at maximum static pressure of 120 bar. The vessel may be used as a safety vessel or filled itself with a hydrogen-air mixture at different pressures from several 10 mbar to 120 bar of absolute pressure. It has a semi-spherical cover to open/close whole cross-section of the vessel. Different installations and specimens as pipelines, valves and high-pressure hydrogen tanks can be put inside the vessel for testing. The vessel is equipped with measuring ports and windows for visual observations. The existing gas-filling system allows creating either inert atmosphere or hydrogen-air mixtures at different concentrations and pressures. Hydrogen injection into the evacuated or pressurized vessel may also be investigated. The measuring system consists of thermocouples array (gas temperature, flame arrival time), piezoelectric and piezoresistive gauges (initial pressure, explosion pressure), gas analyzer and mass spectrometer (to control mixture composition), photodiodes and ion probes (flame arrival time, flame speed), strain gauges (deformations). The data acquisition system is based on multi-channel (64) ADC with a sampling rate of 1 MHz. The vessel was successfully tested for hydrogen jet injection and combustion at sub-atmospheric pressure of 200 mbar. Another testing was for 350 bar hydrogen tanks rupture under external mechanical pressure load.

Main research area(s) of the infrastructure / laboratory
Turbulent hydrogen combustion in uniform and nonuniform gas mixtures at different pressures; effect of venting on flame propagation regimes; high pressure hydrogen releases, experiments on hydrogen distribution, hydrogen jet combustion, structural response of piping structures to internal pressure loads, integrity of high pressure tanks under external and internal pressure loads, to use as a safety vessel for small hydrogen inventory facilities (as explosion tubes and chambers, hydrogen fuel cells).

Instruments and tools available for the above mentioned research
Vacuum pump, Hydro-press (up to 50 ton), Hydrogen (or other gas) injection system, high speed imaging system combined with BOS technique.



Name of the organization
Karlsruher Institut für Technologie (KIT)

Name of the infrastructure / laboratory
HYKA-HPEB (a High Pressure Explosion Bomb)

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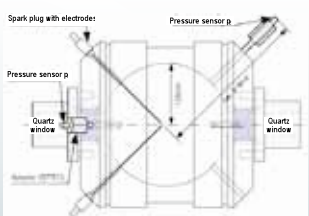
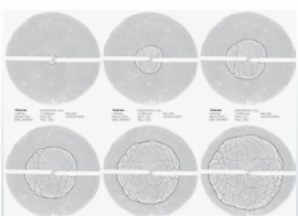
Main field of activity of the infrastructure / laboratory
- *Hydrogen safety, hydrogen storages*

Short description of the infrastructure / laboratory
The High Pressure Explosion Bomb (HPEB) is a spherical volume of 8.2 dm3 and internal diameter of 25 cm with a wall thickness of →34 mm equipped with two quartz windows for optical observations. The explosion bomb was used to investigate flammability limits, minimum ignition energy, laminar flame velocity, and flame structure for different hydrogen-air and hydrogen-oxygen mixtures with or without steam at different pressures from several 10 mbar to 800 bar and temperature in the range of 20-300 oC. The vessel is equipped with measuring ports for pressure transducers and thermocouples and as well as windows for visual observations. The existing gas-filling system based on mass flow controllers allows creating hydrogen-air mixtures at different concentrations and pressures. The measuring system consists of thermocouples array (gas temperature), piezoelectric and piezoresistive gauges (initial pressure, explosion pressure), gas analyzer and mass spectrometer (to control mixture composition). The data acquisition system is based on multi-channel (64) ADC with a sampling rate of 1 MHz. The vessel was successfully tested for hydrogen explosion at 70 bar of initial pressure and temperatures up to 300 oC.

Main research area(s) of the infrastructure / laboratory
Such fundamental properties as flammability limits, laminar flame velocity, minimum ignition energy for hydrogen compositions with air, oxygen, steam and other gases at different pressures and temperatures.

Instruments and tools available for the above mentioned research
Vacuum pump, gas filling system, high speed imaging (up to 200000 fr.p.s.)





Name of the organization
CEA/LITEN

Name of the infrastructure / laboratory
*PRETHY – DTBH/LCTA_*

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Main field of activity of the infrastructure / laboratory
- *Hydrogen Production & Distribution*
- *Hydrogen embrittlement under hydrogen gas pressure*

Short description of the infrastructure / laboratory
The equipment proposed, which is in operation since summer 2007, enables materials to be tested in gaseous hydrogen pressures and temperatures. It is designed to understand how materials are affected by hydrogen embrittlement. A pressure vessel, associated to a hydraulic MTS testing machine allows to perform tensile, fatigue as well as fracture mechanics testing under hydrogen pressure. The influence of hydrogen pressure, temperature, strain rate or time can be carefully analysed. Local extensometers inside the vessel allow measuring the imposed displacement on the specimen. In the same laboratory, a disc rupture facility up to 1000 bar under hydrogen (including impurities such as water) is available. These two equipments are complementary to address hydrogen embrittlement. To analyze the experimental results, a FEM simulation tool has been developed associating hydrogen diffusion to the mechanical fields.

Main research area(s) of the infrastructure / laboratory
The lab is involved on the mechanical behavior of materials. A special skill has been developed concerning the study of hydrogen embrittlement mechanisms of metallic alloys under hydrogen gas. Both experimental and simulation tools have been developed for this purpose.

Instruments and tools available for the above mentioned research
Hydraulic testing machine associated to a pressure vessel operating at pressures up to 350 bar and temperatures up to 350°C. Internal available volume of 5.5 l in the pressure vessel. Two cells to perform disc rupture tests up to 1000 bar and, up to 100°C under pure hydrogen, helium or wet hydrogen.

Mechanical testing and disc rupture tests under hydrogen pressure devices

Name of the organization
CEA/LITEN

Name of the infrastructure / laboratory
DTBH/LTH (COMEDHY)

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Main field of activity of the infrastructure / laboratory
- *Hydrogen Production & Distribution*
- *Hydrogen Storage in Hydrides*

Short description of the infrastructure / laboratory
The equipment proposed, which is in operation since January 2010, named COMEDHY, enables hydrides materials to be tested in gaseous hydrogen pressures and temperatures. It is designed to understand how hydride behaves in terms of swelling and shrinking under mechanical constraints during absorbing and desorbing hydrogen. The vessel operates at pressures from 0 to 200 bar and temperatures up to 200°C, with an internal volume of 50ml-150ml of hydride.
The influence of the applied mechanical force can be assessed during a few tens of absorption/desorption cycles. A full temperature measurement inside the hydride and the vessel allows establishing the link between mechanical stresses between the hydride and its container and the thermal efficiency of the hydriding reaction. The current method for measuring the absorbed volume is based on the use of mass flow devices. As a consequence, the experiment needs a minimum mass of hydride, absorbing at least 10 Nl of hydrogen.

Main research area(s) of the infrastructure / laboratory
Hygrogen Storage by Hydride in demonstrators at a significant scale.

Instruments and tools available for the above mentioned research
Large Glove Box for preparing samples and loading the testing device.

COMEDHY is the device open for H2FC

Name of the organization
Institute for Energy Technology

Name of the infrastructure / laboratory
JEEP II

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Main field of activity of the infrastructure / laboratory
- *Materials characterization*

Short description of the infrastructure / laboratory
The infrastructure consists of three instruments for neutron scattering measurements at the nuclear reactor JEEP II. The instruments are used for structural characterization of materials form the atomic level to the nanometer scale. The techniques are especially useful for hydrogen containing materials since the neutrons are strongly scattered by the light hydrogen atoms.

Main research area(s) of the infrastructure / laboratory
Structural characterization of hydrogen storage materials.

Instruments and tools available for the above mentioned research
PUS: *A high-resolution powder neutron diffractometer*
ODIN: *A multi-purpose neutron diffractometer for high-resolutions or in-situ studies*
SANS: *Small Angle Neutron Scattering instruments for investigations of nanometer-sized objects*

The PUS instrument

The SANS instrument

H2PF

Name of the organization
European Commission DG-JRC, Institute for Energy and Transport

Name of the infrastructure / laboratory
Hydrogen production Performance characterization Facility (H2PF)

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Main field of activity of the infrastructure / laboratory
- *Stationary and Fuel Cells for Power and Heat Generation*
- *Transportation and Refueling Infrastructure*
- *Cross-cutting issues*

Short description of the infrastructure / laboratory
The Hydrogen production Performance characterization Facility (H2PF) comprises of a small scale hydrogen production unit (reformer) based on reforming of low calorific natural gas to high purity hydrogen as fuel cell feed and an online monitoring of reformer input and output fluid and energy streams to survey quality of feeds and products and to determine performance in terms of efficiency and CO2 emissions under various operation modes. So far, very little research is ongoing to support the definition of test protocols and their experimental validation on the energy conversion and environmental performance of small scale reformers.

Main research area(s) of the infrastructure / laboratory
reformer testing; hydrogen production

Name of the organization
European Commission DG-JRC, Institute for Energy and Transport

Name of the infrastructure / laboratory
SolTeF – Solid-state hydrogen storage Testing Facility

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Main field of activity of the infrastructure / laboratory
- *Transportation and Refueling Infrastructure*

Short description of the infrastructure / laboratory
The SolTeF laboratory is dedicated to measure the hydrogen sorption parameters employing commercially available, state-of-the-art experimental set-ups based on volumetric, gravimetric and spectrometric methods. What makes SolTeF rare is first of all its independency from material development centres, and its focusing on accuracy and repeatability of hydrogen sorption measurements. SolTeF offers analytical services for assessment of hydrogen storage parameters, such as overall capacity, pressure-composition isotherms (PCI), thermal gravimetric analysis (TGA), thermal desorption spectroscopy (TDS) and reaction kinetic curves. Long term cycling behaviour studies are also possible using an in-house developed device.

Main research area(s) of the infrastructure / laboratory
Testing the hydrogen sorption properties of solid state materials potentially interesting from hydrogen storage point of view

Instruments and tools available for the above mentioned research
Gravimetric and volumetric based gas sorption analyzers covering the operation ranges from LN2 – 500 degC temperature and from 0 – 200 bars pressure; TDS-MS coupled analyzers for measurements from LN2 temp. up to 500 degC and pressure up to 130 bars. Ball mill and glove-boxes for sample preparation and storage.

Name of the organization
European Commission DG-JRC, Institute for Energy and Transport

Name of the infrastructure / laboratory
GasTeF: High Pressure Gas Testing Facility

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Main field of activity of the infrastructure / laboratory
- *Transportation and Refueling Infrastructure*

Short description of the infrastructure / laboratory
GasTeF is a unique facility among the publicly funded research centres in Europe, because it can test under real conditions full scale high-pressure components using hydrogen as a medium. Vehicle storage components (mainly tanks) are pressure-cycled for a pre-defined number of cycles. A typical cycle will consist of 3 minutes filling time and ca. 20 minutes emptying to the low pressure.
GASTEF consists basically of a two-stage compressor and a testing chamber equipped with temperature control and hydrogen tank diagnostics such as thermocouples, pressure gauges and a gas chromatograph. These components are installed in a safety bunker filled with nitrogen during experiments and protecting the external environment from every possible accidental situation. The facility is designed to be able to fill in an hydrogen container to a pressure 880 MPa within 5 minutes and to slowly empty it. Permeation rates and temperature evolution can be continuously monitored and life cycle studies can be performed.

Main research area(s) of the infrastructure / laboratory
High pressure hydrogen storage tanks testing

Instruments and tools available for the above mentioned research
High pressure piston compressor, hydrogen pre-cooler, system for inside tank temperature measurement, gas chromatograph for hydrogen permeation measurements, the facility is fully automated and remotely controlled.

ETC

Name of the organization
European Commission DG-JRC, Institute for Energy and Transport

Name of the infrastructure / laboratory
Environmental Test Chamber (ETC)

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Main field of activity of the infrastructure / laboratory
- *Stationary and Fuel Cells for Power and Heat Generation*
- *Transportation and Refueling Infrastructure*
- *Cross-cutting issues*

Short description of the infrastructure / laboratory
The Environmental Test Chamber (ETC) comprises a unique combination of a walk-in environmental chamber housing a six-degrees-of-freedom (6DoF) computerized vibration test system with provisions foreseen to test up to 100 kW fuel cells or other test items. The environmental conditions include the simultaneous application of multi-axial shocks & vibration at frequencies of up to 250 Hz (i.e. field test data), ambient temperatures in the range of -40°C to +60°C and 15-95% relative humidity of the ambient. Such environmental conditions are most relevant for hydrogen and fuel cells in transport application including the use of portable and mobile devices as well as the safe transport of stationary devices to and from the installation site. The design and the safe, reliable and durable operation of such devices in these applications require the definition and experimental validation of test protocols and the testing (e.g. structural integrity) under a variety of environmental conditions (ambient temperature & humidity, vibrations & shocks). Moreover, this chamber is equipped with safety features such as gas sensors and ex-proof surveillance cameras linked to a video recording device.

Main research area(s) of the infrastructure / laboratory
Environmental testing

Name of the organization
National Center for Scientific Research "Demokritos"

Name of the infrastructure / laboratory
HYSORB

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Main field of activity of the infrastructure / laboratory
- *Hydrogen Storage*

Short description of the infrastructure / laboratory
HYSORB is a highly specialized and well-equipped gas and vapour sorption laboratory. Its facilities congregate an extended collection of state-of-the-art, top-class and complementary instrumentation that allows accurate gas (e.g. N_2, H_2, CO_2, CH_4) and vapour (e.g. H2O) sorption measurements in well controlled sample environment at different pressure/temperature conditions (vacuum - 200 bar, 9 - 600 K) and scales (material quantities from mg to kg bed scale), for the study of physisorption and chemisorption phenomena in solid materials. The experimental possibilities can be significantly supported by simulation tools developed in-house, that provide an integrated approach exploiting the benefits between material and process design. Atomistic/Molecular level simulations (e.g. GCMC supported by DFT and/or abinitio methods) can be used for the characterisation of materials based on their gas sorption characteristics (N2, CO2, H2) but also as a prediction tool for their gas sorption performance under different conditions.

Main research area(s) of the infrastructure / laboratory
Thorough characterization of textural properties (surface area, porosity, pore size and volume, density, surface acidity etc.) of porous materials, ceramics, powders, membranes, polymers etc.; determination of H2 storage performance (sorption capacity, kinetics, thermodynamics, cycling) of solids including typical H2 stores (carbons, MOFs, metal hydrides); water sorption and permeability measurements (that could also serve battery and fuel cell research).

Instruments and tools available for the above mentioned research
HYSORB laboratory offers a wide range of volumetric, gravimetric, calorimetric and spectroscopic techniques such as: an Intelligent Gravimetric Analyser (IGA, 77-600 K, vac-20 bar), a magnetically suspended Rubotherm balance (vac-200 bar, 77-1000 K), two commercial (PCT-Pro and VTI HPVA 100) volumetric systems (0-200 bar, 77-600 K, one of them is also equipped with a micro-dosing module for accurate PCT measurements on very small sample quantities), two low pressure (<1 bar) high resolution volumetric apparatuses, a customised Thermal Desorption Spectroscopy coupled with MS rig (9-600 K), a Setaram C80 gas tight Calvet Calorimeter (1-350 bar, ambient–600K), a TGA/DSC/MS system (300-1500 K). Additionally, a set of gas and vapor permeability rigs are available, including a commercial automated unit (Dansensor PBI) specially designed for polymeric membranes.

Name of the organization
Università degli Studi di Perugia

Name of the infrastructure / laboratory
MCLab

Address and country of the infrastructure / laboratory
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Main field of activity of the infrastructure / laboratory
- *Material characterization by means of x-ray, neutron, light*

Short description of the infrastructure / laboratory
The MCLab can provide the microscopic material analysis in a wide space and energy range, depending on the specific needs. Standard x-ray diffraction on powder and small angle diffraction can be performed. The x-ray diffraction can be performed at low temperature down to 10 K and at high temperature up to 1000 K with a variety of wavelength. In the case of the most demanding environment, highly penetrating 60 keV photons can be employed. Additional information on the chemical status of the material can be gained using the measurement of the Compton profile either at medium energy (22 keV) or with the penetrating 60 keV radiation. Support in different application of neutron scattering and radiography can be provided. Other specific probes like atomic force and scanning microscope are available. All these techniques are well suited to study the performance of the different materials in the case of PEM fuel cell in situ or ex situ.

Main research area(s) of the infrastructure / laboratory
Structure and dynamic characterization of condensed matter

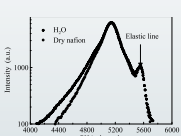
Instruments and tools available for the above mentioned research
Four x-ray sources with monochromatic beams ranging from the Cr Ka wavelength up to the W ka wavelength and continuous radiation up to 300 keV photon energy. Wide range of sample temperature from 10 K up to 1000 K for diffraction experiments, including Bragg and diffuse scattering. Appropriate devices to measure the Compton profile at 22 keV and 60 keV photon energy. Neutron analysis, microscopy techniques, light absorption techniques.

Fluorescence and Compton acquisition system

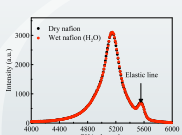
Low temperature wide angle diffractomer

High energy four circle x-ray diffractometer

X-ray fluorescence and Compton scattering spectrometer



Raw Compton profile of liquid water and dry nafion membrane



Raw Compton profile of dry and wet nafion membrane

Name of the organization
ENEA (Italian National Agency for New Technologies, Energy and Sustainable Economic Development)

Name of the infrastructure / laboratory
CR Casaccia / Molten Salt Experiments (MOSE)

Address and country of the infrastructure / laboratory
ENEA C.R. Casaccia - Via Anguillarese 301 – 00123 Rome, Italy

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Angelo Moreno

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Main field of activity of the infrastructure / laboratory
- *Hydrogen production*

Short description of the infrastructure / laboratory
The MOSE facility is in operation since 2007, and covers the experimental needs related to materials characterization in molten salt flowing condition. It is suitable for dynamic corrosion testing and all other durability testing of steels, sealing, welding, etc. The experimental results of such facility is necessary for proper engineering of molten salt devices such as heat collecting elements, heat exchangers, pumps, valves, storage tanks, etc. Hence, MOSE facility is potentially adaptable to thermochemical plants requiring up to 40 kW of thermal power at 550°C for R&D studies on solar-hydrogen production at the pilot/bench scale. In this case, the solar plant is simulated by means of an electrical heater.

Main research area(s) of the infrastructure / laboratory
Materials characterization in molten salt flowing condition

Access not available yet.
Information on the installation will be further updated.

Name of the organization
ENEA (Italian National Agency for New Technologies, Energy and Sustainable Economic Development)

Name of the infrastructure / laboratory
CCR Casaccia / Prova Collettori Solari (PCS)

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Main field of activity of the infrastructure / laboratory
- *Hydrogen production*

Short description of the infrastructure / laboratory
The PCS facility is the main testing loop built in ENEA and it is unique in the world. It consist in a two lines of high temperature parabolic trough collector using as heat transfer fluid a binary component salt (60% of sodium nitrate and 40% of potassium nitrate) operating up to 550°C. This facility is in operation since 2004 and it is composed of a totally instrumented molten salt closed loop and a molten salt storage tank (5 m3 capacity), electric heaters and salt-air heat exchangers. Its task is the testing under real operating condition of all the main plant components (parabolic solar collector, supporting structure, mirrors, tracking and driving systems, heat collecting elements, molten salt components, circulating pumps, sensors, valves, preheating systems, etc.) and setting up operating procedure of a molten salt solar field: operation and maintenance procedures, control loops, draining and filling procedures, etc. It is noteworthy that this facility is potentially adaptable to thermochemical plants requiring up to 500 kW of thermal power at 550°C for proof-of-concept and demonstration studies on solar-hydrogen production at the pilot level.

Access not available yet.
Information on the installation will be further updated.

Name of the organization
ENEA (Italian National Agency for New Technologies, Energy and Sustainable Economic Development)

Name of the infrastructure / laboratory
CR Casaccia / SIH2 cycle Laboratory (SIH2 Loop)

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Main field of activity of the infrastructure / laboratory
- *Hydrogen production*

Short description of the infrastructure / laboratory
SI_Loop consists of a bench scale chemical loop for the Sulfur-Iodine thermochemical water-splitting cycle. In this laboratory plant, all wet elements are made of glass or fluoropolymers. In the actual configuration the plant is designed to operate at pressures close to atmosphere; however, this facility is flexible to integration with improved components with minor modifications: for example, operations in the hydriodic acid decomposition section can be replaced with a single reactive distillation column, operating at high pressures, to improve cycle efficiency. A fully equipped chemical laboratory to investigate the unit operations involved in the process is also available. The demonstration plant is composed of three main sections, corresponding to the three main reactions of the chemical cycle: Bunsen section, HI decomposition section, and sulphuric acid decomposition section.

Main research area(s) of the infrastructure / laboratory
This plant allows H2 production (from water) at a constant rate of ca. 10 Nl/h, without the use of electrochemical cells, since the whole cycle is powered by heat at maximum 850°C. Hence, this facility allows development of the chemical plant in the perspective of its coupling with solar or next generation high-temperature nuclear plants. In this facility the external heat input is simulated by means of electrical heaters (Joule effect) whose overall power is the order of 10 kW. Particularly, this facility allows to: study each unit operation (separations, reactions, etc.) individually to identify best operative conditions; study the coupling between units; improve know-how on the S-I cycle management and train personnel; identify critical process steps to focus further research efforts to improve efficiency and feasibility; develop start-up and shut-down operations; collect performance data for the design of larger-scale (pilot, full-scale) equipment. The same facility can be also employed to study a new sulphur recovery process, based on the "open cycle" S-I process, where industrial sulphur wastes (solid sulphur, hydrogen sulphide, sulphur dioxide) are converted to hydrogen with or without concentrated sulphuric acid as by-product (this process involves only reactions 1 and 2).

Instruments and tools available for the above mentioned research
This laboratory has chemical cabinets equipped with gas monitoring systems and specific gas cabinet and dispensers to provide and manage harmful gases like hydrogen iodide and sulphur dioxide; besides, the laboratory is fully equipped with standard analytical instrumentation to analyze the process stream (e.g. ionic chromatography, hydrogen analysers, gas chromatography).

Access not available yet.
Information on the installation will be further updated.

Name of the organization
ENEA (Italian National Agency for New Technologies, Energy and Sustainable Economic Development)

Name of the infrastructure / laboratory
CR Casaccia /Nanoparticled, nanostructured and high surface materials laboratory (NANO Lab)

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Main field of activity of the infrastructure / laboratory
- *Hydrogen storage*

Short description of the infrastructure / laboratory
The technology of High Energy Ball Milling (HEBM) devoted to synthesize and processing new materials, consists in treating solid state powder reagents so that repeated energy transfer events from the milling media (generally balls) to the milled powder occur. Mechanical energy release induces several physico-chemical transformations on the milled substrate: powder compounding (metal-ceramic composite mixtures can be obtained), Mechanical Alloying of metallic mixtures and even chemical synthesis of products starting from reagents can be obtained (Mechanosynthesis). Remarkable in this field is the possibility to synthesize systems of complex oxides. Due to the non equilibrium conditions of the powder treatment, materials produced by these processing technology (nanostructured and nanoparticled) exibit peculiar characteristics none otherwise obtainable. HEBM is an enabling technology whose characteristics can lead to a sensible improvement in the whole hydrogen cycle system.

Main research area(s) of the infrastructure / laboratory
The following techniques are ruotinerely use as processing characterization tools: high temperature reactive atmosphere powder X-ray diffraction, SEM, thermal analysis (TG, DTA, DSC), light scattering (1nm-6um particle diameter range), surface area analyser (BET), thermal programmed desorbtion/reaction (TPD/TPR). The following technical items can be investigted in the field of: Thermochemical Hydrogen Production, Hydrogen storage, Hydrogen purification from Steam Reforming and/or other gases (CH4, CO,....) storage and purification, PEMFC, MCFC, SOFC

Access not available yet.
Information on the installation will be further updated.

Name of the organization
ENEA (Italian National Agency for New Technologies, Energy and Sustainable Economic Development)

Name of the infrastructure / laboratory
ENEA C.R. Casaccia - Via Anguillarese 301 – 00123 Rome, Italy

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Main field of activity of the infrastructure / laboratory
- *Hydrogen Storage*

Short description of the infrastructure / laboratory
The PCT is a gas sorption analyzer capable of measuring a number of properties including gas absorption/desorption and cycling capacity of gas-solid interactions. The possibility to set the working temperature up to 500°C and to increase the pressure up to 80 bar allow to test hydrogen storage materials with different physical-chemical properties. The maximum hydrogen flow, 500ml min-1, allow to measure large quantity of sample. From different temperature measurements the enthalpies of reaction and the activation energy can be also evaluated. A user friendly interface allows a simple utilization of the instrumentation.
The PARR Hydrogenation system is a gas sorption analyzer capable of measuring gas absorption/desorption capacity and cycling properties of gas-liquid interactions. The volume of the vessel is 600 ml. The stirred vessel allows testing hydrogenation reactions at pressure up to 200 bar. The temperature can be accurately adjusted up to 350°C. The process controller can handle a wide variety of inputs and outputs to control gas flows and reaction temperature. The motor control provides true closed loop feedback control of the reactor stirring speed. The PARR Hydrogenation system has a PC interface custom tailored to the application.

Instruments and tools available for the above mentioned research
PARR: the system consists of six parts: hydraulic circuit with valves and flow meter; heater control unit; cooling system; oven and sample holder; process control unit; hydrogen supplier. It works in a batch mode, where all reactants are charged into the reactor before the reaction is started.
PCT: The system consists of six parts: a two stage vacuum pump; hydraulic circuit with valves and flow meters; heater control unit; oven and sample holder (2 or 200cc); process control unit; hydrogen supplier.

Access not available yet.
Information on the installation will be further updated.

Name of the organization
TECNALIA RESEARCH & INNOVATION

Name of the infrastructure / laboratory
HYMAT

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Main field of activity of the infrastructure / laboratory
- *Cross-cutting issues*
- *Materials Behaviour*

Short description of the infrastructure / laboratory
The Hydrogen-MATerials testing activity (HyMAT) of TECNALIA is supported in several testing equipment that allow an evaluation of the behaviour of materials in hydrogen service conditions.The effect of hydrogen in the mechanical properties of materials can be evaluated by some series of testing. Hydrogen Assisted Stress Cracking (HASC): The sensitivity of materials to HASC is evaluated by a combination of mechanical, corrosion and electrochemical testing. The hydrogen can be produced by chemical or electrochemical ways. After the test, the specimen is characterized by means of chemical analysis and optical and scanning electron microscopy.

Main research area(s) of the infrastructure / laboratory
Materials behaviour , Hydrogen Embrittlement

Instruments and tools available for the above mentioned research
Main equipment used in this Laboratory consists of mechanical testing machines, electrochemical equipment, hydrogen sulfide source, chemical and microstructural characterization equipments and general laboratory equipment.

Hydrogen Assisted Stress cracking testing configuration based on SSRT equipment

Hydrogen Assisted Stress cracking testing configuration based on dynamometric rings

Microstructural and Chemical Characterization Equipment

Name of the organization
SINTEF Material and Chemistry - Oslo

Name of the infrastructure / laboratory
SINTEF-1: Membranes and Materials Research Laboratory (MMRL)

Address and country of the infrastructure / laboratory
Forskningsveien 1, NO-0314 Blindern, Oslo, Norway

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Main field of activity of the infrastructure / laboratory
- *Stationary and Fuel Cells for Power and Heat Generation*
- *Hydrogen Production & Distribution*

Short description of the infrastructure / laboratory
The Membranes and Materials Research Laboratory facility at SINTEF in Oslo is dedicated to characterisation of advanced ceramic materials and membranes for high temperature gas separation and high temperature fuel cell applications. Material synthesis and thorough characterization is covered as well as membrane and fuel cell development and high temperature/high pressure testing of individual components and small modules/ stacks. An advanced gas distribution infrastructure for multiple gasses (O2, H2, N2, CO, CO2, CH4, Ar, He, ...) and mixtures thereof is installed. The gas mass flow and pressure controllers are regulated by a PC and the gas composition of feed and permeate is monitored continuously by MS and GC units. Equipment is available for testing of fuel cell efficiency, hydrogen flux in membranes, conductivity measurements etc. This state-of-the-art facility has thus high degree of automation for gas control and monitoring. It provides data for studies of reactions kinetics, transport properties, and stability of materials e.g. used as adsorbents and membranes.

Main research area(s) of the infrastructure / laboratory
Hydrogen production by ceramic and metallic high temperature membranes
Characterisation of PCFC and SOFC fuel cells

Instruments and tools available for the above mentioned research
- ProboStatTM units enabling membrane permeation measurements up to 1100 °C and 5 bar pressure
- Various in-house designed units allow for studies of permeation up to 40 bars and 600 °C (e.g. for studies of Water Gas Shift or Methane Steam Reforming)
- 3 TG measurement units that give the possibility to investigate materials from ambient conditions to high pressure (40 bars) – high temperature (1100 °C) conditions in the presence of harsh chemicals

Name of the organization
Empa Switzerland, Eidgenoessische Materialspruefungs- und Forschungsanstalt

Name of the infrastructure / laboratory
Laboratory for the Development of Materials for Hydrogen production (Lady)

Address and country of the infrastructure / laboratory
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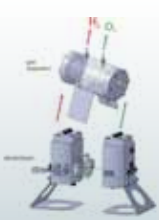
Main field of activity of the infrastructure / laboratory
- *Hydrogen Production & Distribution*

Short description of the infrastructure / laboratory
(a) High Temperature Electrolysis by Solid Oxide Cells (SOEC)
Structural investigations (PSD, grain growth and coarsening effects, pore size distribution and grain boundary aspects), determination of chemical changes, material interactions and diffusion processes after long operation time in the µm and nm scale. Phase changes as well as nucleation and growth of new phases can be analysed by conventional XRD or into details by Synchrotron analysis.
(b) Alkaline electrolysis (laboratory scale). Tests carried out using electrolysis test apparatus (Fig. 2) developed by the Electrochemistry group of the laboratory Hydrogen & Energy, provide the results on the diaphragm/membranes' gas separation properties and their impact on the cell voltage. Monitored hydrogen and oxygen gas purity, together with the cell voltage, are critical parameters for ranking the efficiency of the newly developed membranes.
(c) Electrochemical characterization. Electrochemical Impedance Spectroscopy (EIS) is suitable for gathering better understanding of the ion conductivity of diaphragms/membranes. For this purpose, a two compartment 4-electrode electrochemical cell controlled by Zahner IM6eX potenstiostat/galvanostat is used (Fig. 3). Moreover, electrochemical techniques, such as linear/cyclic voltametry, are undertaken in order to characterize the corrosion behavior of material.

Main research area(s) of the infrastructure / laboratory
Hydrogen storage, hydrogen production, synthetic fuels, batteries, surface science, materials synthesis and characterization, electrochemistry

Instruments and tools available for the above mentioned research
Standard solid state preparation methods (ball-milling) - Structural investigations by XRD, REM - Membrane performance test stand - Electrochemical impedance spectroscopy



Name of the organization
Empa Switzerland, Eidgenoessische Materialspruefungs- und Forschungsanstalt

Name of the infrastructure / laboratory
Laboratory for Solid Hydrogen Storage Materials (Lasy), Empa

Address and country of the infrastructure / laboratory
Empa, Laboratory Hydrogen & Energy, Überlandstrasse 129, CH 8600 Dübendorf

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Main field of activity of the infrastructure / laboratory
- *Hydrogen Production & Distribution*

Short description of the infrastructure / laboratory
(a) Synthesis of Hydrogen storage materials via solid state preparation methods such as ball-milling. (b) Characterisation of Hydrogen storage materials via state of the art characterization methods such as volumetry. A variety of techniques can be offered to evaluate the key parameters of hydrogen storage materials, such as surface area determination by nitrogen adsorption measurements at 77 K: BELSORP-max (BEL, Japan), structural characterization by Raman spectroscopy as well as by in situ X-ray diffraction in various atmospheres (H2, H2O), and temperatures up to 800°C (Bruker D8). Gravimetric measurements are possible in inert atmosphere or under hydrogen of up to 200 bar in a modified RUBOTHERM magnetic suspension balance. The chemical composition of the desorbed gas are measured by thermal desorption mass spectroscopy (Balzers). The measurement of surface compositions is made possible by an X-ray photoelectron spectrometer (Specs). All sample preparation, handling and measurements are performed without contact to air.

A particular highlight is the possibility of combining different characterization tools, such as:
XRD and simultaneous volumetric sorption analysis / Gravimetry with simultaneous gas analysis by infrared spectroscopy and mass spectroscopy / Gravimetry with in-situ Raman spectroscopy / X-ray photoelectron spectroscopy and simultaneous gas analysis by mass spectroscopy.

Main research area(s) of the infrastructure / laboratory
Hydrogen storage, hydrogen production, synthetic fuels, batteries, surface science, materials synthesis and characterization, electrochemistry

Instruments and tools available for the above mentioned research
Standard solid state preparation methods (ball-milling) / XRD and simultaneous volumetric sorption analysis / Gravimetry with simultaneous gas analysis by infrared spectroscopy and mass spectroscopy / Gravimetry with in-situ Raman spectroscopy / X-ray photoelectron spectroscopy and simultaneous gas analysis by mass spectroscopy.


Materials preparation


Hydrogen storage properties


Materials Characterization

FUEL CELLS

COUNTRY	PARTNER	INSTALLATION	TECHNOLOGY EXPERT
Germany	KIT	SOFC Test Lab	andre.weber@kit.edu
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UK	NPL	Electrochem Test	gareth.hinds@npl.co.uk
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SOFC Test Laboratory

Name of the organization
Karlsruher Institut für Technologie (KIT)
Institut für Werkstoffe der Elektrotechnik (IWE)

Name of the infrastructure / laboratory
SOFC Test Laboratory

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Main field of activity of the infrastructure / laboratory
- *Electrochemical characterization of solid oxide fuel cells*

Short description of the infrastructure / laboratory
At KIT-IWE a number of SOFC testing facilities are available for SOFC- material, electrode and single cell tests. The facility enables a detailed electrochemical characterization under realistic operating conditions including. The results can provide information about the individual loss mechanisms in the cell and their dependencies on operating conditions (temperature, gas composition, gas utilization and current density). Based on the results electrochemical models for the cell can be developed.

Main research area(s) of the infrastructure / laboratory
Analysis of electrochemical properties of solid oxide fuel cells

Instruments and tools available for the above mentioned research
Test Benches for SOFC single cells

SOFC test benches

Setup and housing for single cell tests

Microprober for conductivity measurements

HYKA-PZ

Name of the organization
Karlsruher Institut für Technologie (KIT)

Name of the infrastructure / laboratory
HYKA-PZ (a Hydrogen Test Chamber)

Address and country of the infrastructure / laboratory
Karlsruher Institut für Technologie (KIT), Campus Nord, Hermann-von-Helmholtz-Platz 1 - 76344 Eggenstein-Leopoldshafen, Germany

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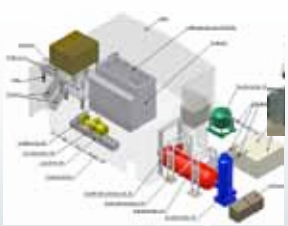
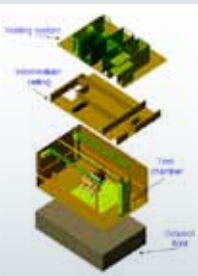
Main field of activity of the infrastructure / laboratory
- *Hydrogen safety, transportation, refueling, hydrogen storages*

Short description of the infrastructure / laboratory
The hydrogen test chamber consists of three floors (see figure 1) and is located in a larger building on the hydrogen test site HYKA of the KIT. The ground floor contains the concrete footing of the cell floor, the second storey is the test chamber itself and the third storey houses its venting system. The test chamber has an internal volume of approx. 160 m3 (8.53 m x 5.5 m x 3.3 m), so the powerful venting system that produces air flows of up to 24.000 m3/h allows exchanging its internal atmosphere two times within one minute. The air flow can be arranged to circulate around samples and both supply- and exhaust-air-system to the ambience are explosion proof. High pressure hydrogen jet release and hydrogen jet development, its ignition in a stagnant atmosphere or in presence of active ventilation is the main purpose of this facility. It is possible to test automotive hydrogen engines Inside the 160 m3 test cham¬ber (KIT-PZ). The space inside the chamber is sufficient for even a complete hydrogen powered passenger car. Furthermore the powerful venting system allows creating air flows around samples comparable to a wind tunnel or even with a more complex flow structure. The integrity of the chamber was tested in detonation experiments with up to 16 g H2, even larger amount of hydrogen (up to 64 g H2) is possible in case of deflagration process. For all experiments in HYKA compressed hydrogen (CGH2) or cryogenic liquid hydrogen (LH2) are available.

Main research area(s) of the infrastructure / laboratory
Hydrogen combustion and detonation, high pressure hydrogen releases, cryogenic hydrogen releases, laminar flame velocity, flammability and self-ignition limits for hydrogen-air mixtures, structural response of piping structures to internal pressure loads, car testing to the effects of internal hydrogen explosion, ventilation system efficiency





Name of the organization
Commissariat à l'énergie atomique et aux energies alternatives (CEA)

Name of the infrastructure / laboratory
EDIP consisting in INAC (Institut NAnoscience et Cryogénie) et Liten (Laboratoire d'Innovation pour les Technologies des Energies Nouvelles et les Nanomatériaux)

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Main field of activity of the infrastructure / laboratory
- *Stationary and Fuel Cells for Power and Heat Generation*

Short description of the infrastructure / laboratory
The EDIP installation and associated procedures allow determining the membrane water content in an operating fuel cell by small-angle neutron scattering using specific cells, transparent to neutrons (25cm2, golden aluminum plates with visualization holes along the gas channels and temperature controlled), and a mobile test bench (25 cm2 single cell capability, humidity and gas flow mass controlled and monitored, temperature monitoring from room temperature to 100°C). Operation conditions such as temperature or current densities can be varied over a representative range. A data analysis protocol has also been developed to extract the water concentration profiles within the membrane during operation. These data can be used either to validate mass transfer models, to measure water transport at given humidity values or to study the water management in specific conditions. In addition all in situ experimentations are prepared using regular normalized test benches available at CEA/Grenoble.

Main research area(s) of the infrastructure / laboratory
Studies on the structure and water transport properties of ionic conducting membranes along with in-situ water repartition during fuel cell operation by Nautron and/or X-Ray scattering

Instruments and tools available for the above mentioned research
Fuel cell test bench and single cell test fixutes designed for the study of water management and repartition during fuel cell operation. Laboratory Small Angle X-Ray Scattering (SAXS) beamline. Possibility for help in writing proposals for access to large european facilities such as European Synchrotron Radiation Facility (ESRF), Institu Laue Langebvin (ILL) and Laboratoire Leon Brillouin (LLB).

Laboratory Small Angle X-Ray Scattering (SAXS) beamline

Single Cell test fixture and facility at ILL for the study of water repartition during operation by Small Angle Neutron Scattering (SANS)

Single Cell test fixture and facility at ESRF for the study of water repartition during operation by Small Angle X-Ray Scattering (SAXS)

H2QF

Name of the organization
European Commission DG-JRC, Institute for Energy and Transport

Name of the infrastructure / laboratory
Hydrogen fuel and air Quality test Facility (H2QF)

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Main field of activity of the infrastructure / laboratory
- *Stationary and Fuel Cells for Power and Heat Generation*
- *Transportation and Refueling Infrastructure*
- *Cross-cutting issues*

Short description of the infrastructure / laboratory
The Hydrogen fuel and air Quality test Facility (H2QF) which is just commissioned by JRC, is composed of dedicated high purity gas supply lines connected to a 3 kW PEFC/DMFC test station combined with a dual (EI/IMR) mass spectroscopy gas analyzer to quantify and monitor FC feeds and emissions for the assessment of the effects of hydrogen fuel quality and air contaminants on the performance (and degradation) of single cells and short stacks. This includes the establishment of cross contaminant effects which is a too least studied scientific issue to urgently identify tolerable fuel quality of hydrogen when produced by different production methods (electrolysis, reforming, gasification, fermentation, etc) and to refine hydrogen fuel specifications (for fuel cell use).

Main research area(s) of the infrastructure / laboratory
Testing of PEFC single cells and short stacks

Instruments and tools available for the above mentioned research
FC test station to simulate various test conditions.

Name of the organization
European Commission DG-JRC, Institute for Energy and Transport

Name of the infrastructure / laboratory
Environmental Test Chamber (ETC)

Address and country of the infrastructure / laboratory
Westerduinweg 3, 1755 LE Petten, The Netherlands

Person responsible of the access / Contact person
T Malkow

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+31 224 565656 / +31 224 565625 / http://iet.jrc.ec.europa.eu / Thomas.malkow@jrc.nl

Main field of activity of the infrastructure / laboratory
- *Stationary and Fuel Cells for Power and Heat Generation*
- *Transportation and Refueling Infrastructure*
- *Cross-cutting issues*

Short description of the infrastructure / laboratory
The Environmental Test Chamber (ETC) comprises a unique combination of a walk-in environmental chamber housing a six-degrees-of-freedom (6DoF) computerized vibration test system with provisions foreseen to test up to 100 kW fuel cells or other test items. The environmental conditions include the simultaneous application of multi-axial shocks & vibration at frequencies of up to 250 Hz (i.e. field test data), ambient temperatures in the range of -40°C to +60°C and 15-95% relative humidity of the ambient. Such environmental conditions are most relevant for hydrogen and fuel cells in transport application including the use of portable and mobile devices as well as the safe transport of stationary devices to and from the installation site. The design and the safe, reliable and durable operation of such devices in these applications require the definition and experimental validation of test protocols and the testing (e.g. structural integrity) under a variety of environmental conditions (ambient temperature & humidity, vibrations & shocks). Moreover, this chamber is equipped with safety features such as gas sensors and ex-proof surveillance cameras linked to a video recording device.

Main research area(s) of the infrastructure / laboratory
Environmental testing

H2PF

Name of the organization
European Commission DG-JRC, Institute for Energy and Transport

Name of the infrastructure / laboratory
Hydrogen production Performance characterization Facility (H2PF)

Address and country of the infrastructure / laboratory
Westerduinweg 3, 1755 LE Petten, The Netherlands

Person responsible of the access / Contact person
T Malkow

Phone / Fax / Web / Email
+31 224 565656 / +31 224 565625 / W. http://iet.jrc.ec.europa.eu / Thomas.malkow@jrc.nl

Main field of activity of the infrastructure / laboratory
- *Stationary and Fuel Cells for Power and Heat Generation*
- *Transportation and Refueling Infrastructure*
- *Cross-cutting issues*

Short description of the infrastructure / laboratory
The Hydrogen production Performance characterization Facility (H2PF) comprises of a small scale hydrogen production unit (reformer) based on reforming of low calorific natural gas to high purity hydrogen as fuel cell feed and an online monitoring of reformer input and output fluid and energy streams to survey quality of feeds and products and to determine performance in terms of efficiency and CO2 emissions under various operation modes. So far, very little research is ongoing to support the definition of test protocols and their experimental validation on the energy conversion and environmental performance of small scale reformers.

Main research area(s) of the infrastructure / laboratory
Reformer testing; hydrogen production

Name of the organization
Forschungszentrum Jülich GmbH

Name of the infrastructure / laboratory
Institute of Energy and Climate Research / IEK-9: Principles of Electrochemistry

Address and country of the infrastructure / laboratory
Wilhelm Johnen Str, 52425 Jülich, Germany

Person responsible of the access / Contact person
L.G.J. de Haart

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Main field of activity of the infrastructure / laboratory
- *Fuel Cells for stationary power and heat generation*

Short description of the infrastructure / laboratory
Facility for single cell testing of Solid Oxide Fuel Cells / Single cell (ASC and/or ESC) dimensions: square 50x50 mmxmm or round diameter 20 mm / Testing with humidified (3%) hydrogen against air / Testing from 600 up to 900 °C

Main research area(s) of the infrastructure / laboratory
Electrochemical processes and materials for fuel cells, batteries and electrolyzers

Instruments and tools available for the above mentioned research
High temperature electrochemical test facilities for fuel cells, batteries and electrolyzers / Cyclic voltammetry, chrono-amperometry, impedance spectroscopy

Name of the organization
Paul Scherrer Institut (PSI)

Name of the infrastructure / laboratory
SINQ, imaging stations NEUTRA and ICON / Electrochemistry Laboratory (ECL) and Neutron Imaging and Activation Group (NIAG)

Address and country of the infrastructure / laboratory
Paul Scherrer Institut (PSI), 5232 Villigen PSI, Switzerland

Person responsible of the access / Contact person
Pierre Boillat, Electrochemistry Laboratory

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Main field of activity of the infrastructure / laboratory
- *Stationary and Fuel Cells for Power and Heat Generation*

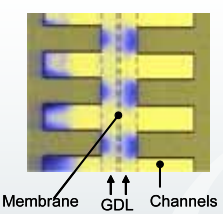
Short description of the infrastructure / laboratory
The 2 imaging beam lines at the SINQ spallation source of PSI provide state-of-the-art neutron imaging including advanced detector technology. Imaging is performed with thermal neutrons (NEUTRA beam line) or cold neutrons (ICON beam line). The PSI Electrochemistry Laboratory (ECL) and the PSI Neutron Imaging and Activation Group (NIAG) have developed in situ neutron imaging of liquid water in operating fuel cells in close collaboration over the past ten years. Such developments included the creation of detectors with anisotropic resolution enhancement, specifically targeted for the cross sectional imaging of fuel cells.

Main research area(s) of the infrastructure / laboratory
PSI Electrochemistry Laboratory (ECL): Research on materials, system aspects and characterization technologies in the field of electrochemical energy storage and conversion (e.g. fuel cells, batteries). Neutron Imaging and Activation Group (NIAG): Research on neutron imaging technology and its application to different research fields (e.g. material science, energy research, archeology).

Instruments and tools available for the above mentioned research
NEUTRA and ICON neutron imaging beam lines / Wide range of detector options
Mobile fuel cell test bench for experiments in the beam lines / For specific projects: ECL setup for simultaneous imaging of 6 fuel cells

The neutron spallation source SINQ at PSI

The neutron imaging beam line ICON



High resolution imaging of water distribution in an operating PEFC (false color representation)

The ECL setup for simultaneous operation and imaging of 6 fuel cells, in the ICON beam line

Name of the organization
University of Perugia

Name of the infrastructure / laboratory
Fuel Cell Laboratory (CDS, SOFC, MCFC test benches)

Address and country of the infrastructure / laboratory
Via G. Duranti 67, 06125 Perugia, Italy

Person responsible of the access / Contact person
Umberto Desideri

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+39 075.585.3991 / +39 075.858.3991 / www.fclab.unipg.it / fclab@unipg.it

Main field of activity of the infrastructure / laboratory
- *Stationary and Fuel Cells for Power and Heat Generation*

Short description of the infrastructure / laboratory
The FCLab is 152 square metres. It is equipped with plants of gas distribution, facilities of data control and saving, gascromatography and systems for the measurement of concentration, impedance analyzer, gas and H2O controllers, temperature control systems, current control systems, systems of pressure measurement, desulphurization system. The Lab has developed and used test benches for single cell testing and small (1kW and 2.5kWe) fuel cell stacks. Up to date, FCLab is provided with: one 2.5 KWe SOFC test bench; one 300 W SOFC test bench; one 3 W SOFC test bench; one 16 W SOFC test bench; one 11 W MCFC test bench; one 300 Kwe MCFC test bench. FC Lab is also provided with desulphurization test bench including: gas distribution system made up of Teflon pipes and Sulfinert T junctions; analysis section of the outlet gas; data acquisition system. The whole system is wrapped in a rack and connected to an extractor hood.

Main research area(s) of the infrastructure / laboratory
SOFC/MCFC POWER PRODUCTION (Fuel processing, Clean-up, Performances, System integration); CARBON CAPTURE; μCHP

Instruments and tools available for the above mentioned research
Each test rig is fed with hydrogen, nitrogen, carbon monoxide, carbon dioxide and air. A control system measures and controls gas flows, temperature, current and voltages. System modeling is developed via Aspen Tech and Cycle Tempo.




Name of the organization
Università degli Studi di Perugia

Name of the infrastructure / laboratory
MCLab

Address and country of the infrastructure / laboratory
Dipartimento di Fisica dell'Università degli Studi di Perugia, Via Alessandro Pascoli, Perugia, Italy

Person responsible of the access / Contact person
Prof. Francesco Sacchetti

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Main field of activity of the infrastructure / laboratory
- *Material characterization by means of x-ray, neutron, light*

Short description of the infrastructure / laboratory
The MCLab can provide the microscopic material analysis in a wide space and energy range, depending on the specific needs. Standard x-ray diffraction on powder and small angle diffraction can be performed. The x-ray diffraction can be performed at low temperature down to 10 K and at high temperature up to 1000 K with a variety of wavelength. In the case of the most demanding environment, highly penetrating 60 keV photons can be employed. Additional information on the chemical status of the material can be gained using the measurement of the Compton profile either at medium energy (22 keV) or with the penetrating 60 keV radiation. Support in different application of neutron scattering and radiography can be provided. Other specific probes like atomic force and scanning microscope are available. All these techniques are well suited to study the performance of the different materials in the case of PEM fuel cell in situ or ex situ.

Main research area(s) of the infrastructure / laboratory
Structure and dynamic characterization of condensed matter

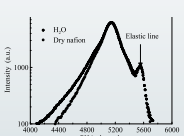
Instruments and tools available for the above mentioned research
Four x-ray sources with monochromatic beams ranging from the Cr Ka wavelength up to the W ka wavelength and continuous radiation up to 300 keV photon energy. Wide range of sample temperature from 10 K up to 1000 K for diffraction experiments, including Bragg and diffuse scattering. Appropriate devices to measure the Compton profile at 22 keV and 60 keV photon energy. Neutron analysis, microscopy techniques, light absorption techniques.

Fluorescence and Compton acquisition system

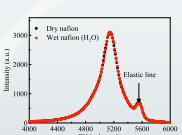
Low temperature wide angle diffractomer

High energy four circle x-ray diffractometer

X-ray fluorescence and Compton scattering spectrometer



Raw Compton profile of liquid water and dry nafion membrane



Raw Compton profile of dry and wet nafion membrane

Name of the organization
ENEA (Italian National Agency for New Technologies, Energy and Sustainable Economic Development)

Name of the infrastructure / laboratory
CR Casaccia / PEMFC, SOFC, MCFC Fuel cell testing Laboratory

Address and country of the infrastructure / laboratory
ENEA C.R. Casaccia - Via Anguillarese 301 – 00123 Rome, Italy

Person responsible of the access / Contact person
Angelo Moreno

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+39 0630484298 / +39 0630486306 / www.enea.it / angelo.moreno@enea.it

Main field of activity of the infrastructure / laboratory
- *Fuel cells – transportation and refuelling*

Short description of the infrastructure / laboratory
The FC testing laboratory consists of four laboratories: three of them consist of single cell and stack test benches for performance evaluation and degradation mechanism investigation of PEMFC, MCFC and SOFC. The forth laboratory is dedicated to chemical-physical characterization of cell and stack component both pre and post test. The access to these 4 laboratories will allow the user to the complete characterization of systems based either on PEM or on MCFC or on SOFC taking into account the specification needed for a peculiar application.

Main research area(s) of the infrastructure / laboratory
Tests can be conducted to test performance and endurance for transport applications both for FC car/bus (PEM) but also as system for APU - Auxiliary power unit on board cars, buses, tracks, ship, caravan, boats... (SOFC, MCFC).

Access not available yet.
Information on the installation will be further updated.

Name of the organization
National Physical Laboratory

Name of the infrastructure / laboratory
Gas chromatography measurement of hydrogen purity to current international standards using traceable reference materials

Address and country of the infrastructure / laboratory
National Physical Laboratory, Hampton Road, Teddington, Middlesex, TW11 0LW, United Kingdom

Person responsible of the access / Contact person
Andrew Brown

Phone / Fax / Web / Email
+442089436831 / andrew.brown@npl.co.uk

Main field of activity of the infrastructure / laboratory
- *Measurements of hydrogen purity*

Short description of the infrastructure / laboratory
NPL has a dedicated world-leading gas chromatography laboratory with multiple high performance gas chromatograph systems, with the ability to characterise a wide range of analytes at very low impurity levels. The chromatograph systems available are as follows:
GC – mass spectrometry / GC – thermal conductivity detection / GC – flame ionisation detection / GC – sulphur chemiluminescence detection / GC – pulsed helium discharge ionisation detection.
The work we have been focusing on in this area has been on identifying key impurities at the levels specified in the latest drafts (or published versions of) ISO 14687-2 and 14687-3 on hydrogen purity. Resolution will be improved to sub ppm levels during project.

Main research area(s) of the infrastructure / laboratory
Gas purity analysis

Instruments and tools available for the above mentioned research
Gas chromatography.

Name of the organization
National Physical Laboratory

Name of the infrastructure / laboratory
Instrumented single cell PEMFC test stations

Address and country of the infrastructure / laboratory
National Physical Laboratory, Hampton Road, Teddington, Middlesex, TW11 0LW, United Kingdom

Person responsible of the access / Contact person
Gareth Hinds

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+442089437147 / gareth.hinds@npl.co.uk

Main field of activity of the infrastructure / laboratory
- *PEMFC – in situ measurement and modeling*

Short description of the infrastructure / laboratory
NPL has a dedicated PEMFC research laboratory equipped with a range of novel in situ measurement techniques, with the principal focus on studying fuel cell degradation modes such as startup/shutdown and cell reversal. The facility contains two highly instrumented Hydrogenics single cell test stations, supported by a range of material and electrochemical characterisation techniques. Available techniques include unique capability for in situ measurement of relative humidity in PEMFC flowfield channels and localised current density measurement using a segmented electrode. Ground-breaking in situ reference electrode capability will be added during this project.

Main research area(s) of the infrastructure / laboratory
In situ measurement and modeling of PEMFCs

Instruments and tools available for the above mentioned research
Instrumented single cell PEMFC test stations, potentiostats, hydrogen generator.

National Physical Laboratory
Electrochem Test

Name of the infrastructure / laboratory
Electrochemical techniques for characterisation of catalyst performance

Address and country of the infrastructure / laboratory
National Physical Laboratory, Hampton Road, Teddington, Middlesex, TW11 0LW, United Kingdom

Person responsible of the access / Contact person
Gareth Hinds

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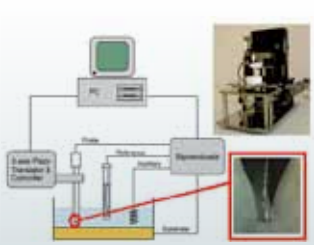
+442089437147 / gareth.hinds@npl.co.uk

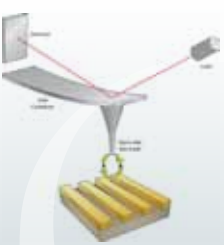
Main field of activity of the infrastructure / laboratory
- *Electrochemical characterization of fuel cell catalysts*

Short description of the infrastructure / laboratory
NPL has extensive facilities for electrochemical characterisation of fuel cell catalysts, including state of the art scanning electrochemical microscopy (SECM) and rotating disk electrode (RDE). SECM enables the characterisation of electrocatalyst materials through mapping of surface reactivity under relevant aqueous environments. Conventionally a microelectrode probe is scanned at a fixed distance from the substrate and electrolytic processes are driven and monitored locally by the probe to detect spatial variations in catalyst behaviour and activity. In the simplest case the activity of a catalyst sample towards the hydrogen oxidation reaction can be probed in acidic electrolytes, but the experiment can be tailored to a range of reactive systems (e.g. oxygen reduction reaction) and conditions (e.g. pH, solvent medium). Spatial resolution is typically of the order of microns across scanning areas as large as several millimetres. Information about electrochemical kinetics is also obtainable through probe approach curves at points of interest. RDE experiments can be undertaken to gain kinetic information about electrocatalytic processes by lifting mass transport limitations. Typically catalyst particles are immobilized onto a carbon RDE substrate and electrocatalytic activity with respect to the hydrogen oxidation and oxygen reduction reactions is measured through linear sweep and potential step measurements under controlled conditions.

Main research area(s) of the infrastructure / laboratory
Development of nanoscale electrochemical probes

Instruments and tools available for the above mentioned research
Scanning electrochemical microscope with high resolution, rotating disk electrode.





SINTEF-1: MMRL

Name of the organization
SINTEF Material and Chemistry - Oslo

Name of the infrastructure / laboratory
SINTEF-1: Membranes and Materials Research Laboratory (MMRL)

Address and country of the infrastructure / laboratory
Forskningsveien 1, NO-0314 Blindern, Oslo, Norway

Person responsible of the access / Contact person
Rune Bredesen / Thijs Peters

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+47 98 24 39 41 / +47 22 06 73 50 / www.sintef.no / thijs.peters@sintef.no

Main field of activity of the infrastructure / laboratory
- *Stationary and Fuel Cells for Power and Heat Generation*
- *Hydrogen Production & Distribution*

Short description of the infrastructure / laboratory
The Membranes and Materials Research Laboratory facility at SINTEF in Oslo is dedicated to characterisation of advanced ceramic materials and membranes for high temperature gas separation and high temperature fuel cell applications. Material synthesis and thorough characterization is covered as well as membrane and fuel cell development and high temperature/high pressure testing of individual components and small modules/ stacks. An advanced gas distribution infrastructure for multiple gasses (O2, H2, N2, CO, CO2, CH4, Ar, He, ...) and mixtures thereof is installed. The gas mass flow and pressure controllers are regulated by a PC and the gas composition of feed and permeate is monitored continuously by MS and GC units. Equipment is available for testing of fuel cell efficiency, hydrogen flux in membranes, conductivity measurements etc. This state-of-the-art facility has thus high degree of automation for gas control and monitoring. It provides data for studies of reactions kinetics, transport properties, and stability of materials e.g. used as adsorbents and membranes.

Main research area(s) of the infrastructure / laboratory
Hydrogen production by ceramic and metallic high temperature membranes
Characterisation of PCFC and SOFC fuel cells

Instruments and tools available for the above mentioned research
- *ProboStatTM units enabling membrane permeation measurements up to 1100 °C and 5 bar pressure*
- *Various in-house designed units allow for studies of permeation up to 40 bars and 600 °C (e.g. for studies of Water Gas Shift or Methane Steam Reforming)*
- *3 TG measurement units that give the possibility to investigate materials from ambient conditions to high pressure (40 bars) - high temperature (1100 °C) conditions in the presence of harsh chemicals*

SINTEF-PEM

Name of the organization
SINTEF Material and Chemistry

Name of the infrastructure / laboratory
SINTEF-PEM durability diagnostics lab

Address and country of the infrastructure / laboratory
Sem Sælandsve1 12, NO-7465 Trondheim, Norway

Person responsible of the access / Contact person
Paul Inge Dahl and Anders Ødegård

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+47 98243955 and +47 94356595/ +47 73591105 / www.sintef.no / paul.inge.dahl@sintef.no

Main field of activity of the infrastructure / laboratory
- *Stationary and Fuel Cells for Power and Heat Generation*
- *Hydrogen Production & Distribution*

Short description of the infrastructure / laboratory
The PEM durability diagnostics lab gives the opportunity to investigate the state-of-health and degradation of PEM electrolyzers and fuel cells, at single cell and short stack level. Complete electrochemical equipped test stations are combined with advanced on-line and post mortem analysis. By working in the PEM durability diagnostics lab, it is possible to combine extensive online diagnostics with post mortem analysis. Electrochemical characterisation of the cells/stacks will show the degree ofdegradation and processes occurring in the PEM cells and its components, while online gas/liquid analysis (MS, FTIR and LC/IC) supports these results and reveal further parameters for understanding the processesand changes in component properties. SEM and TEM are also available for post mortem investigations ofcomponents. This lab is currently in use in several international projects related to PEM fuel cell and electrolyzerdevelopment and degradation investigations. Among them are 3 FCH JU projects, with both industry andacademia partners with interest in the test labs capabilities.

Main research area(s) of the infrastructure / laboratory
PEM fuel cells and electrolyzers characterization.

Instruments and tools available for the above mentioned research
The methods and equipment available include electrochemical impedance spectroscopy, cyclic voltammetry, mass spectroscopy, fourier transform infrared spectroscopy, liquid/ Ion chromatography, scanning electron microscope, transmission electron microscopy, nuclear magnetic resonance (liquid/solid). Cells and short stacks from a few cm2 and up to 300 cm2 are eligible for these test stations.

SAFETY ISSUES

COUNTRY	PARTNER	INSTALLATION	TECHNOLOGY EXPERT
Germany	KIT	HYKA (IKET) / HYKA	mike.kuznetsov@kit.edu
Germany	KIT	HYKA-A2 Facility	mike.kuznetsov@kit.edu
Germany	KIT	HYKA-A1 Facility	mike.kuznetsov@kit.edu
Germany	KIT	HYKA-A3 Facility	mike.kuznetsov@kit.edu
Germany	KIT	HYKA-A6 Facility	mike.kuznetsov@kit.edu
Germany	KIT	HYKA-PET	mike.kuznetsov@kit.edu
Germany	KIT	HYKA-ST	mike.kuznetsov@kit.edu
Germany	KIT	PROFLAM I & II	mike.kuznetsov@kit.edu
France	CEA	FLOREAL	isabelle.tkatschenko@cea.fr gilles.bernard-michel@cea.fr
UK	HSE	HiPress	roger.brentnall@hsl.gov.uk
UK	HSE	TunEn	roger.brentnall@hsl.gov.uk
UK	HSE	ExCell	roger.brentnall@hsl.gov.uk
The Netherlands	JRC	SenTeF	lois.brett@ec.europa.eu
Germany	BAM	TTS-F	ulrich.schmidtchen@bam.de
Germany	BAM	Sens	thomas.huebert@bam.de
Germany	BAM	Trib	ulrich.schmidtchen@bam.de

Name of the organization
Karlsruher Institut für Technologie (KIT)

Name of the infrastructure / laboratory
HYKA (IKET) / HYKA

Address and country of the infrastructure / laboratory
Karlsruher Institut für Technologie (KIT), Campus Nord, Hermann-von-Helmholtz-Platz 1 - 76344 Eggenstein-Leopoldshafen, Germany

Person responsible of the access / Contact person
Dr. Mike KUZNETSOV

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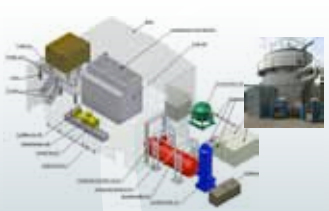
Main field of activity of the infrastructure / laboratory
- *Hydrogen safety, transportation, refueling, hydrogen storages*

Short description of the infrastructure / laboratory
At the hydrogen test centre HYKA of the Karlsruhe Institute of Technology (KIT) there are several safety vessels and test tubes for hydrogen combustion experiments in various sca¬les and a large test chamber for hydrogen distribution and in particular combustion experi¬ments. In particular: Hydrogen Test Chamber (PZ); Safety-Vessels A1, A2, A3, A8; Explosion tubes. The experimental facilities constituting the hydrogen test site HYKA are among the largest available in Europe. In combination with the high static and dynamic pressures the experimental facilities are designed for a unique experimental centre especially for combu¬stion experiments in confined spaces is available with HYKA. Inside the 160 m3 test cham¬ber (KIT-PZ), for example, it is possible to test automotive hydrogen engines, and space is sufficient for even a complete hydrogen powered passenger car. Furthermore the powerful venting system allows creating air flows around samples comparable to a wind tunnel or even with a more complex flow structure. Since the integrity of the chamber was tested in combustion experiments with up to 16 g H2, even detonation experiments at relevant scales are possible. Due to the different orientations and sizes (the internal volumes of the safety vessels A1 with 110m3 and A3 with 60 m3 can be flexibly combined), the set of large and strong experimental vessels offer a flexible basis for scientific experimental work on reacti¬ve hydrogen mixtures. Depending on the purpose, large samples can be tested inside them, or the whole vessel can be used as a test volume. For all experiments in HYKA compressed (CGH2) or cold liquid hydrogen (LH2) are available. Due to the numerous vents, ports and windows versatile instrumentation of a sample inside the safety vessel is possible. The HYKA explosion tubes allow basic combustion experiments with uniform and non-uni¬form gas mixtures at different initial pressures. The smaller tube additionally offers the possibility to investigate the effects of variable transverse vent openings on the combustion process. It is even possible to conduct experiments with a combustible surrounding atmos¬phere, which can be generated inside a thin polyethylene film around the tube.

Main research area(s) of the infrastructure / laboratory
Hydrogen combustion and detonation, high pressure hydrogen releases, laminar flame velocity, flammability and self-ignition limits for hydrogen-air mixtures, structural response of piping structures to internal pressure loads, high pressure tank testing to mechanical and thermal loads, car testing to the effects of internal hydrogen explosion, cryogenic hydrogen releases, ventilation system efficiency



Name of the organization
Karlsruher Institut für Technologie (KIT)

Name of the infrastructure / laboratory
HYKA-A2 Facility (a Large Scale Explosion Chamber)

Address and country of the infrastructure / laboratory
Karlsruher Institut für Technologie (KIT), Campus Nord, Hermann-von-Helmholtz-Platz 1 - 76344 Eggenstein-Leopoldshafen, Germany

Person responsible of the access / Contact person
Dr. Mike KUZNETSOV

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Main field of activity of the infrastructure / laboratory
- *Hydrogen safety, refueling, hydrogen storages*

Short description of the infrastructure / laboratory
The largest safety vessel A2 with main dimensions of 6 m id and 9 m height provides an empty test volume of about 220 m3. It is designed for fire and explosion tests with an operating over-pressure from -1 to 10 bar. Depending on the purpose, large samples can be tested inside them, or the whole vessel can be used as a test volume. The vessel may be evacuated or filled with inert atmosphere of nitrogen or steam and may be heated up to 150 oC. The vessel is equipped with many vents and ports for experiment and measurement set-ups as well as with windows for visual observations. It has 3 vents of 2000 mm id, 4 vents of 700 mm id, 5 vents of 400 mm id and about 40 vents of smaller inner diameters (50-250 mm). The measuring system consists of thermocouples array (gas temperature, flame arrival time); piezoelectric and piezoresistive gauges (initial pressure, explosion pressure); gas analyzer and mass spectrometer (to control mixture composition); sonic hydrogen sensors, photodiodes and ion probes (flame arrival time, flame speed), strain gauges (deformations). The data acquisition system is based on multi-channel (64) ADC with a sampling rate of 1 MHz. The vessel was successfully tested using 2 large scale combustion experiments of hydrogen-steam-air mixture (10:25:75 = H2:H2O:air) at 1.5 bar of initial pressure and 90 oC temperature.

Main research area(s) of the infrastructure / laboratory
Turbulent hydrogen combustion in uniform and nonuniform gas mixtures at different initial pressures and temperatures; effect of venting on flame propagation regimes; high pressure hydrogen releases, experiments on hydrogen distribution in closed volume, structural response of piping structures to internal pressure loads, bon fire testing of high pressure tanks, integrity of high pressure tanks under external and internal pressure loads, to use as a safety vessel for small hydrogen inventory facilities (as explosion tubes and chambers, hydrogen fuel cells and forklifts).

Instruments and tools available for the above mentioned research
Vacuum pump, steam generator, high speed imaging system combined with BOS technique.

Name of the organization
Karlsruher Institut für Technologie (KIT)

Name of the infrastructure / laboratory
HYKA-A1 Facility (a Large Scale Safety Vessel)

Address and country of the infrastructure / laboratory
Karlsruher Institut für Technologie (KIT)
Campus Nord, Hermann-von-Helmholtz-Platz 1 - 76344 Eggenstein-Leopoldshafen, Germany

Person responsible of the access / Contact person
Dr. Mike KUZNETSOV

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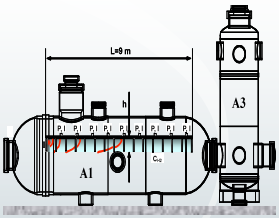
+49 721 60824716 / +49 721 60824777 / mike.kuznetsov@kit.edu

Main field of activity of the infrastructure / laboratory
- *Hydrogen safety, refueling, hydrogen storages*

Short description of the infrastructure / laboratory
The safety vessel A1 has main dimensions of 3.5 m id and 12 m length with a volume of 100 m3. It was certified at maximum static pressure of 100 bar. The vessel may be used as a safety vessel or filled itself with a hydrogen-air mixture at ambient conditions. A rectangular sub-compartment of 9 x 3 x 0.6 m3 may be used to study a combustion and detonation in a horizontal semi-confined layer of hydrogen air mixture. The vessel is equipped with measuring ports and windows for visual observations. The existing gas-filling system allows creating a layer of hydrogen-air mixtures with a linear vertical concentration gradient from 0.1 to 1.1 %H2/cm. It has a semi-spherical cover to open/close whole cross-section of the vessel. Combined with vessel A3, it can be used for combustion propagation tests in a multi-compartment geometry. The measuring system consists of thermocouples array (gas temperature, flame arrival time); piezoelectric and piezoresistive gauges (initial pressure, explosion pressure); gas analyzer and mass spectrometer (to control mixture composition); sonic hydrogen sensors, photodiodes and ion probes (flame arrival time, flame speed), strain gauges (deformations). The data acquisition system is based on multi-channel (64) ADC with a sampling rate of 1 MHz. The vessel was successfully tested for detonation of 16 m3 of stoichiometric hydrogen-air mixture at ambient pressure and temperature.

Main research area(s) of the infrastructure / laboratory
Turbulent hydrogen combustion in uniform and nonuniform gas mixtures at ambient conditions; flame acceleration and detonation experiments in confined and semi-confined geometries, effect of venting on flame propagation regimes; high pressure hydrogen releases, experiments on hydrogen distribution, structural response of piping structures to internal pressure loads, integrity of high pressure tanks under external and internal pressure loads, to use as a safety vessel for small hydrogen inventory facilities (as explosion tubes and chambers, hydrogen fuel cells and forklifts).

Instruments and tools available for the above mentioned research
Hydrogen injection system, rectangular sub-compartment of 9 x 3 x 0.6 m3 with of without obstruction grid, high speed imaging system combined with BOS technique.



Name of the organization
Karlsruher Institut für Technologie (KIT)

Name of the infrastructure / laboratory
HYKA-A3 Facility (a Large Scale Vertical Vessel)

Address and country of the infrastructure / laboratory
Karlsruher Institut für Technologie (KIT), Campus Nord, Hermann-von-Helmholtz-Platz 1 - 76344 Eggenstein-Leopoldshafen, Germany

Person responsible of the access / Contact person
Dr. Mike KUZNETSOV

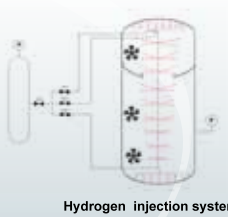
Phone / Fax / Web / Email
+49 721 60824716 / +49 721 60824777 / mike.kuznetsov@kit.edu

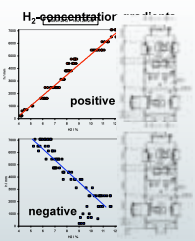
Main field of activity of the infrastructure / laboratory
- *Hydrogen safety*

Short description of the infrastructure / laboratory
The safety vessel A3 has main dimensions of 2.5 m id and 8 m height with a volume of 33 m3. It was certified at maximum static pressure of 60 bar. The vessel may be evacuated or filled with a hydrogen-air mixture at different pressures from sub-atmospheric to several bar of initial pressure. Having a sub-volume of 11 m3 together with system of obstructions it can be used for combustion propagation tests in a multi-compartment geometry. The existing gas-filling system allows creating nonuniform hydrogen-air mixtures with a "positive" or "negative" (related to the gravity) vertical concentration gradient from 0.1 to 1.0 %H2/m. The vessel is equipped with measuring ports and windows for visual observations. The measuring system consists of thermocouples array (gas temperature, flame arrival time); piezoelectric and piezoresistive gauges (initial pressure, explosion pressure); gas analyzer and mass spectrometer (to control mixture composition); photodiodes and ion probes (flame arrival time, flame speed). The data acquisition system is based on multi-channel (64) ADC with a sampling rate of 1 MHz. The vessel was successfully tested for detonation of 16 m3 of stoichiometric hydrogen-air mixture at ambient pressure and temperature.

Main research area(s) of the infrastructure / laboratory
Turbulent hydrogen combustion in uniform and nonuniform gas mixtures at different pressures; effect of venting on flame propagation regimes; experiments on hydrogen distribution.

Instruments and tools available for the above mentioned research
Hydrogen injection system, obstruction grid


Hydrogen injection systen



Name of the organization
Karlsruher Institut für Technologie (KIT)

Name of the infrastructure / laboratory
HYKA-A6 Facility (a Large Safety Vessel)

Address and country of the infrastructure / laboratory
Karlsruher Institut für Technologie (KIT), Campus Nord, Hermann-von-Helmholtz-Platz 1 - 76344 Eggenstein-Leopoldshafen, Germany

Person responsible of the access / Contact person
Dr. Mike KUZNETSOV

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Main field of activity of the infrastructure / laboratory
- *Hydrogen safety, refueling, hydrogen storages*

Short description of the infrastructure / laboratory
The safety vessel A6 has main dimensions of 3.3 m id and 3.1 m height with a volume of 21.5 m3. It was certified at maximum static pressure of 40 bar. The vessel may be used as a safety vessel for high pressure installations and explosion experiments. It has two doors of 800 mm id. Different installations and specimens as pipelines, valves and high-pressure hydrogen tanks can be put inside the vessel for testing. The vessel is equipped with measuring ports and windows for visual observations. The existing gas-filling system allows creating hydrogen-air mixtures at different concentrations and pressures. The measuring system consists of thermocouples array (gas temperature, flame arrival time), piezoelectric and piezoresistive gauges (initial pressure, explosion pressure), gas analyzer and mass spectrometer (to control mixture composition), photodiodes (flame arrival time, flame speed), strain gauges (deformations). The data acquisition system is based on multi-channel (64) ADC with a sampling rate of 1 MHz. The vessel was successfully tested for pipeline rupture at 1500 bar of explosion pressure. Experiments on integrity of pipelines under internal pressure loads up to 1500 bar have been performed there.

Main research area(s) of the infrastructure / laboratory
Flame acceleration and detonation experiments in confined geometries, high pressure hydrogen releases, experiments on hydrogen distribution, structural response of piping structures to internal pressure loads, integrity of high pressure tanks under external and internal pressure loads, to use as a safety vessel for small hydrogen inventory facilities (as explosion tubes and chambers).

Instruments and tools available for the above mentioned research
Gas filling system, high speed imaging system combined with BOS technique.

Name of the organization
Karlsruher Institut für Technologie (KIT)

Name of the infrastructure / laboratory
HYKA-PET (a Partially Vented Explosion Tube)

Address and country of the infrastructure / laboratory
Karlsruher Institut für Technologie (KIT), Campus Nord, Hermann-von-Helmholtz-Platz 1 - 76344 Eggenstein-Leopoldshafen, Germany

Person responsible of the access / Contact person
Dr. Mike KUZNETSOV

Phone / Fax / Web / Email
+49 721 60824716 / +49 721 60824777 / mike.kuznetsov@kit.edu

Main field of activity of the infrastructure / laboratory
- *Hydrogen safety, transportation, refueling*

Short description of the infrastructure / laboratory
The partially vented explosion tube has an internal diameter of 100 mm and a length of 7 m. It also can be filled with regular ring shaped obstacles with different blockage ratios (BR: 0.3, 0.6), spaced by the tube diameter. Its main features are the variable transverse vent openings, which can be adjusted to vent ratios from 0 to 40%. The tube is connected to a gas filling system and again numerous sensor ports are available. It is equipped with a gas filling system and a large number of sensor ports. The tube offers the possibility to investigate the effects of variable transverse vent openings on the combustion process in order to reproduce flame propagation in a multi-room geometry in presence of openings (like windows and doors in reality). It is even possible to conduct experiments with a combustible surrounding atmos-phere, which can be generated inside a thin polyethylene film around the tube.

Main research area(s) of the infrastructure / laboratory
Hydrogen combustion and detonation in vented areas, deflagration and detonation initiation in partially confined geometries.

Name of the organization
Karlsruher Institut für Technologie (KIT)

Name of the infrastructure / laboratory
HYKA-ST (a Set of Shock Tubes)

Address and country of the infrastructure / laboratory
Karlsruher Institut für Technologie (KIT), Campus Nord, Hermann-von-Helmholtz-Platz 1 - 76344 Eggenstein-Leopoldshafen, Germany

Person responsible of the access / Contact person
Dr. Mike KUZNETSOV

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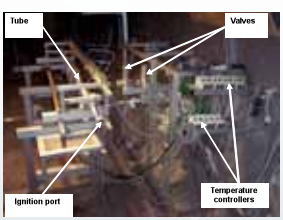
Main field of activity of the infrastructure / laboratory
- *Hydrogen safety, transportation, refueling*

Short description of the infrastructure / laboratory
Several explosion tubes available at the hydrogen test site HYKA: a detonation tube with a length of 12 m and 350 mm id, a tube with a length of 8 m and 50 mm id, a tube with a length of 4 m and 25 mm id, a tube with a length of 12.2 m and 520 mm id. The 12 m detonation tube, for instance, has an internal diameter of 350 mm and is designed for an internal pressure of 100 bar. It is equipped with a gas filling system and a large number of sensor ports. Furthermore it can be equipped with ring shaped obstacles of different blockage ratios (BR: 0.3, 0.45, 0.6, 0.75, 0.9), spaced by the tube diameter. The HYKA explosion tubes allow basic combustion experiments on flame acceleration and detonation transition with uniform mixtures at different initial pressures up to 1500 bar and temperatures up to 300 oC. Pipeline specimens may also be fabricated and tested with respect to integrity of pipelines under internal detonation pressure loads. The tubes in this case may be additionally equipped with strain gauges to monitor a mechanical response of the tube. The measuring system consists of thermocouples array (gas temperature, flame arrival time), piezoelectric and piezoresistive gauges (initial pressure, explosion pressure), gas analyzer and mass flow rate controller (to control mixture composition), photodiodes (flame arrival time, flame speed), strain gauges (deformations). The data acquisition system is based on multi-channel (64) ADC with a sampling rate of 1 MHz. The vessel was successfully tested for pipeline rupture at 1500 bar of explosion pressure.

Main research area(s) of the infrastructure / laboratory
Hydrogen combustion and detonation, critical conditions for flame acceleration and detonation initiation in a tube geometry, mechanical response of pipelines under internal pressure loads

Instruments and tools available for the above mentioned research
Gas filling system, heating sistem



Name of the organization
Karlsruher Institut für Technologie (KIT)

Name of the infrastructure / laboratory
PROFLAM I & II

Address and country of the infrastructure / laboratory
Karlsruher Institut für Technologie (KIT), Campus Nord, Hermann-von-Helmholtz-Platz 1 - 76344 Eggenstein-Leopoldshafen, Germany

Person responsible of the access / Contact person
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Main field of activity of the infrastructure / laboratory
- *Hydrogen-metal dust safety, storages*

Short description of the infrastructure / laboratory
The basic combustion properties of hybrid hydrogen/dust systems may be assessed in the PROFLAM facility. It consists of two combustion tubes, 15 cm and 35 cm (PROFLAM II) of inner diameter. PROFLAM I has three 3-m long sections; each section has 45 measuring ports arranged in nine equidistant cross-sections along the tube axis. Dust dispersion system consists of three independent sub-systems each for one tube section. The tube is rated to 10 bar. PROFLAM II has four 3-m long sections, each section has 28 measuring ports arranged in 8 equidistant cross-sections along the tube axis. Dust dispersion system is the same for all 4 variants of the tube layouts. The tube is rated to 250 bar. Mixtures can be ignited either by strong chemical igniters or by weak electric spark of variable energies, frequencies, and duration. The facility is instrumented with fast pressure measurements (to 100 kHz or higher), thermocouples and photodiodes used as flame-front-arrival gauges, a mass-spectrometer with up to 15 sampling ports arranged along the tube axes, and appropriate data acquisition.

Main research area(s) of the infrastructure / laboratory
Hydrogen-dust combustion, dust mobilization

Name of the organization
Commissariat à l'énergie atomique et aux energies alternatives (CEA)

Name of the infrastructure / laboratory
LEIFT/FLOREAL

Address and country of the infrastructure / laboratory
CEA SACLAY 91191 GIF SUR YVETTE FRANCE

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Main field of activity of the infrastructure / laboratory
- *Hydrogen Production & Distribution*

Short description of the infrastructure / laboratory
At CEA Saclay, Around 7 persons are working on the experimental platform. 3 main infrastructures : GARAGE (a more than 30 sq.m garage room, with a 3D helium concentration sensors mesh, GAMELAN and grand GAMELAN a 1 sq.m and a 2 sq.m box with helium concentration sensors located on 3 vertical lines of 5 sensors, and mistra a more than 100 sq.m able to withstand pressure load). Our main activity consists in performing experiments of helium release in various cavity with very well controlled experimental conditions (temperatures, leakage etc...). We are able to deal with closed or opened (with apertures) cavities, with or without forced ventilation. We mainly measure concentrations distributions of helium vs. time. We are also capable of of measuring the velocity with 3D velocity components PIV systems and also to visualize the flow with boss techniques.

Main research area(s) of the infrastructure / laboratory
Experiments and modeling of gaz dispersion after release in air.

Instruments and tools available for the above mentioned research
Concentration sensors, PIV measuring system with 3-velocity-components capability, Boss visualization system + an experimental facility (industrial hall with bridge-craigs etc...).

Name of the organization
Health and Safety Executive

Name of the infrastructure / laboratory
HiPress-High-Pressure facility

Address and country of the infrastructure / laboratory
Health and Safety Laboratory, Harpur Hilll, Buxton, Derbyshire, SK17 9JN, United Kingdom

Person responsible of the access / Contact person
Dr Roger Brentnall

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+44 (0)1298 218364 / +44 (0)1298 218840 / www.hsl.gov.uk/ - roger.brentnall@hsl.gov.uk

Main field of activity of the infrastructure / laboratory
- *Transportation and Refueling Infrastructure*

Short description of the infrastructure / laboratory
The HSL High pressure hydrogen facility is capable of compressing storing and releasing hydrogen at pressures of up to 1000 bar. The system is engineered for high release flow rates and has a maximum outlet orifice of 9.5 mm. The facility consists of a manifold system for hydrogen and purge gas cylinder packs, this manifold leads to an air operated gas booster system which increases the pressure of the gas and feeds it into two 1000 bar storage vessels each of 50 litres capacity. The control of the facility is automated for fill and release operations and is controlled via a programmable logic controller. The facility can be configured in a number of ways, including transfers between vessels where one vessel represents a filling station dispenser and the second vessel a vehicle tank receiving fuel.

Main research area(s) of the infrastructure / laboratory
High pressure vehicle refueling trials. Testing high pressure relief valves. Investigation of "Spontaneous Ignition" of hydrogen.

Instruments and tools available for the above mentioned research
The control system continuously logs all the system variables such as temperature and pressure. The following parameters can be preset in the control system:
Release pressure - Release duration - Ignition delay - Type of ignition (continuous, single spark or none - Release in response to external event trigger

Name of the organization
Health and Safety Executive

Name of the infrastructure / laboratory
TunEn - Blast tunnel

Address and country of the infrastructure / laboratory
Health and Safety Laboratory, Harpur Hilll, Buxton, Derbyshire, SK17 9JN, United Kingdom

Person responsible of the access / Contact person
Dr Roger Brentnall

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+44 (0)1298 218364 / +44 (0)1298 218840 / http://www.hsl.gov.uk/ - roger.brentnall@hsl.gov.uk

Main field of activity of the infrastructure / laboratory
- *Transportation and Refueling Infrastructure*

Short description of the infrastructure / laboratory
The blast tunnel is a 70 m long tunnel made of steel with a diameter of 3.7 m. The grade of steel used throughout is to BS EN 10025-2 grade S275J2. The tunnel is open at both ends and is supported on concrete plinths. The tunnel consists of an 8 m long central section with a wall thickness of 55 mm. The remaining four sections are 15.5 m long and have a wall thickness of 25 mm. There is a 25 mm gap between each section. The tunnel is designed to withstand a blast equivalent to 15 kg of TNT. Mounds of earth on three sides protect the surroundings. A standard gauge railway track runs through the tunnel from a siding, such that test items can be easily prepared and shunted into the tunnel for testing.

Main research area(s) of the infrastructure / laboratory
Investigation of the effect of deflagration/detonation waves on structures in cylindrical enclosures

Instruments and tools available for the above mentioned research
The facility can accommodate a wide range of devices to record e.g. pressure, temperature, stress/strain and physical movement.

Name of the organization
Health and Safety Executive

Name of the infrastructure / laboratory
ExCell – Explosion Cell

Address and country of the infrastructure / laboratory
Health and Safety Laboratory, Harpur Hilll, Buxton, Derbyshire, SK17 9JN, United Kingdom

Person responsible of the access / Contact person
Dr Roger Brentnall

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Main field of activity of the infrastructure / laboratory
- *Transportation and Refueling Infrastructure*

Short description of the infrastructure / laboratory
The vented enclosure consists of a number of modules, each of which has a 2.5 m x 2.5 m cross section and is 2.5 m long. These modules can be bolted together to give a vessel with a total length of 30 m giving a total internal volume of 187.5 m3. The modules are made of steel and ventilation can be provided by a centrifugal fan with variable fan speed, located at one end of the enclosure. The enclosure can be instrumented as appropriate and fitted with explosion relief, to protect the modules in the event of unexpectedly high pressures being generated during an ignition test.

Main research area(s) of the infrastructure / laboratory
Recent experiments with this facilty have included an assessment of the blast damage to vehicles located inside the modules and pressure measuerments of hydrogen explosions either from a jet release into a congested area or from a static hydrogen-air mixture ignited inside a congested space.

Instruments and tools available for the above mentioned research
Pressure transducers suitable for deflagration measurement - Choked flow orifice plates - Hot wire anemometers - Cages with congestion

The vented enclosure

The end plate
and the centrifugal fan

Name of the organization
European Commission DG-JRC, Institute for Energy and Transport

Name of the infrastructure / laboratory
SenTeF – Hydrogen Sensor Testing Facility

Address and country of the infrastructure / laboratory
Westerduinweg 3, 1755 LE Petten, The Netherlands

Person responsible of the access / Contact person
Lois BRETT

Phone / Fax / Web / Email
+31 224 56 5065 / +31 224 56 5623 / http://iet.jrc.ec.europa.eu/ lois.brett@ec.europa.eu

Main field of activity of the infrastructure / laboratory
- Cross-cutting issues

Short description of the infrastructure / laboratory
The Sensor Testing Facility (SenTeF) of the JRC-IET is a state-of-the-art testing facility dedicated to the characterisation of hydrogen safety sensor performance and reliability. Sensor performance can be assessed under a wide range of environmental conditions. Temperature can be controlled between -40 °C and +130 °C and held constant within ±2 °C. The pressure range of the facility is about 100 Pa up to 250 kPa. Relative humidities of 10% at -10 °C and 100% at 60 °C are possible. A total of four gases may be mixed to produce the desired gas composition. Contaminant species e.g. carbon monoxide or alcohols, can also be introduced to investigate cross sensitivity and poisoning of sensors. A calibrated gas chromatograph and residual gas analyser independently confirm the gas composition which can be compared directly with the sensor output. The facility can be used for evaluating and comparing commercial products or testing sensor platforms under development. Microstructural analytical techniques (SEM, EDS) are also available for investigating changes in the sensing element microstructure following exposure to hydrogen.

Main research area(s) of the infrastructure / laboratory
Hydrogen Safety Sensor Performance Testing

Instruments and tools available for the above mentioned research
Sensor environmental chamber, gas chromatograph, residual gas analyzer, Scanning electron microscope, Energy Dispersive Spectrometer

Name of the organization
BAM Federal Institute for Materials Research and Testing

Name of the infrastructure / laboratory
TTS – Test Site Technical Safety

Address and country of the infrastructure / laboratory
An der Duene 44, 15837 Baruth / Mark, Germany

Person responsible of the access / Contact person
Schmidtchen

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+49 (30) 8104-4402 -3433 / ulrich.schmidtchen@bam.de

Main field of activity of the infrastructure / laboratory
- *Safety*

Short description of the infrastructure / laboratory
This is a test site about 50 im S of Berlin and 12 km² large. It serves for tests concerning dangerous goods, explosives, and similar things. The explosion test ground with a diameter of 400 m enables tests of up to 150 kg of TNT equivalent to be performed. To protect the surroundings the explosion test ground is surrounded by an earth bund. Different pieces of equipment and facilities are available around the explosion test ground to allow the determination of the dangerous characteristics of substances and systems and to test safety devices. In particular fire and explosion tests are carried out. The results are used to ensure safe handling of such materials and objects and the safety of relevant technical equipment. Examples are explosives, pyrotechnical articles, highly enriched materials from the chemical industry, compressed gases as well as storage and transport containers.Two new fire test stands with relevant infrastructure were established on the BAM Test Site Technical Safety in 2008.These measuring stations can be used for open fire tests and research if needed. They are mainly used for the investigation of the internal and external thermal load-bearing capacity of containment systems for dangerous goods such as pressure vessels, storage and transport tanks, packaging and IBC as well as transport and storage tanks for radioactive substances.Thermal energy is provided by burning a liquid propane gas mixture. Liquid gas is injected through the burner nozzles.Heat input of up to 110 kW/m² can be supplied according to the relevant provisions in international regulations, standards and directives.

Name of the organization
BAM Federal Insitute for Materials Research and Testing

Name of the infrastructure / laboratory
Sensor laboratory

Address and country of the infrastructure / laboratory
Unter den Eichen 87, 12205 Berlin, Germany

Person responsible of the access / Contact person
Thomas Huebert

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Main field of activity of the infrastructure / laboratory
◗ *X sensors*

Short description of the infrastructure / laboratory (max 10 lines)
Testing, calibration and validation of gas and humidity sensors

Instruments and tools available for the above mentioned research (max 5 lines)
Testing and calibration of gas sensors / Testing and calibration of humidity sensors Calibration of sensor elements and systems / For the detection of gases, vapours and humidity / Measurement of electrical properties / Thermal analysis (TG, DTA, TMA) Sol-gel coatings

Name of the organization
BAM Federal Institute for Materials Research and Testing

Name of the infrastructure / laboratory
Laboratory for cryotribology

Address and country of the infrastructure / laboratory
Unter den Eichen 87, 12205 Berlin, Germany

Person responsible of the access / Contact person
Schmidtchen

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Main field of activity of the infrastructure / laboratory
- *Materials*

Short description of the infrastructure / laboratory
Laboratory equipped for tests about friction, wear, and lubrication also under cryogenic conditions, including in liquid hydrogen as well as helium or nitrogen.
The cryostats can as well be used for other experiments with cryogenic hydrogen as well as they fit in.

Main research area(s) of the infrastructure / laboratory
Friction

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THOMAS JORDAN
Karlsruhe Institute of Technology (KIT)
E-mail: thomas.jordan@kit.edu

H2FC CONSORTIUM PARTNERS:

KIT: Karlsruhe institute of technology
CEA: Commissariat a l energie atomique et aux energies alternatives
UU: University of Ulster
IFE: Institutt for energiteknikk
HSE: Health and safety executive
JRC: Joint research centre- european commission
JULICH: Forschungszentrum Juelich gmbh
PSI: Paul scherrer Institut
NCSRD: National center for scientific research "demokritos"
UP: University of Perugia
ENEA: Italian national agency for new technologies, energy and sustainable economic development
BAM: Bundesanstalt fuer materialforschung und – pruefung
TECNALIA: Fundacion tecnalia research & innovation tecnalia
UPI: University of Pisa
PS PRO-SCIENCE: Gesellschaft fur wissenschaftliche und technische dienstleistungen mbh
NPL: Npl management limited
SINTEF: Stiftelsen sintef
VTT: Teknologian tutkimuskeskus
EMPA: Eidgenoessische materialpruefungs - und forschungsanstalt

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This version dates
from April 4th 2012.

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a more detailed description
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