Karlsruhe Institute of Technology

Division III – Mechanical and Electrical Engineering

Institute for Thermal Energy Technology and Safety (ITES)

Hydrogen (H2) Department

Hydrogen Storage Systems

Experimental Safety Studies

The current energy crisis clearly shows that Germany as a highly developed industrialized country is dependent on clean, secure, and affordable energy supply. Part of the solution may be hydrogen, as it is the most abundant element in the universe and on Earth. This energy carrier opens up almost infinite opportunities, provided that sufficient renewable energy is available for the production of sustainable green hydrogen. In nature, green hydrogen does not exist in gas form. It has to be produced from water or biomass in an energy-consuming process. Hydrogen is no energy source, but an energy carrier, and, hence, it is comparable to electricity.

Safe Design and Safe Operation

Hydrogen (H_2) is a clean, efficient, and reliable energy carrier for a broad spectrum of applications. Safe handling of H_2 is decisive for the successful introduction of H_2 and fuel cell technologies, although handling of hydrogen is not associated with more risks than handling other energy carriers, including petrol and electricity. Hydrogen produced in a decentralized manner with renewable energies or in countries having more sun and wind could be transported safely in existing gas pipelines or by ship in liquefied form similar to natural gas. A consistent, safe design and safe operation of H_2 production and supply infrastructures must be ensured. This also includes the further development of safety requirements and standards. For applications in the mobility sector and their supply infrastructures, complex geometrical configurations, different safety cultures, and integration in public space with challenging environmental conditions and untrained users must be considered. For this reason, research into the safety of hydrogen use is indispensable.

Hydrogen Research at KIT

KIT's Institute for Thermal Energy Technology and Safety (ITES) has more than 30 years of experience in H_2 safety research and the coordination of the corresponding national and international projects. At its HYKA test center, ITES operates the world's only research facilities of their kind for hydrogen safety experiments of various dimensions.

Experiments can be carried out for various release, combustion, and accident scenarios. Safety studies cover electrolyzers for hydrogen production, hydrogen storage systems, large fuel cells or entire vehicles.

Such studies are required, because physical and chemical properties of hydrogen differ significantly from those of conventional fuels. Under normal conditions, gaseous hydrogen is 14 times lighter than air, which is why it will ascend quickly after release. If no adequate countermeasures are taken, ignitable hydrogen-air mixtures may form below the ceilings of rooms.

Partial view of the HYKA hydrogen test center. (KIT/ITES)

Upon ignition, these may cause highly varying combustion loads depending on the hydrogen concentration.

To quantify these combustion loads, experiments at HYKA focus on combustion of hydrogen-air mixtures in prototype geometries. Potential additional risks of hydrogen technology can then be assessed in comparison with conventional fuels and natural gas.

PET@KIT HYKA

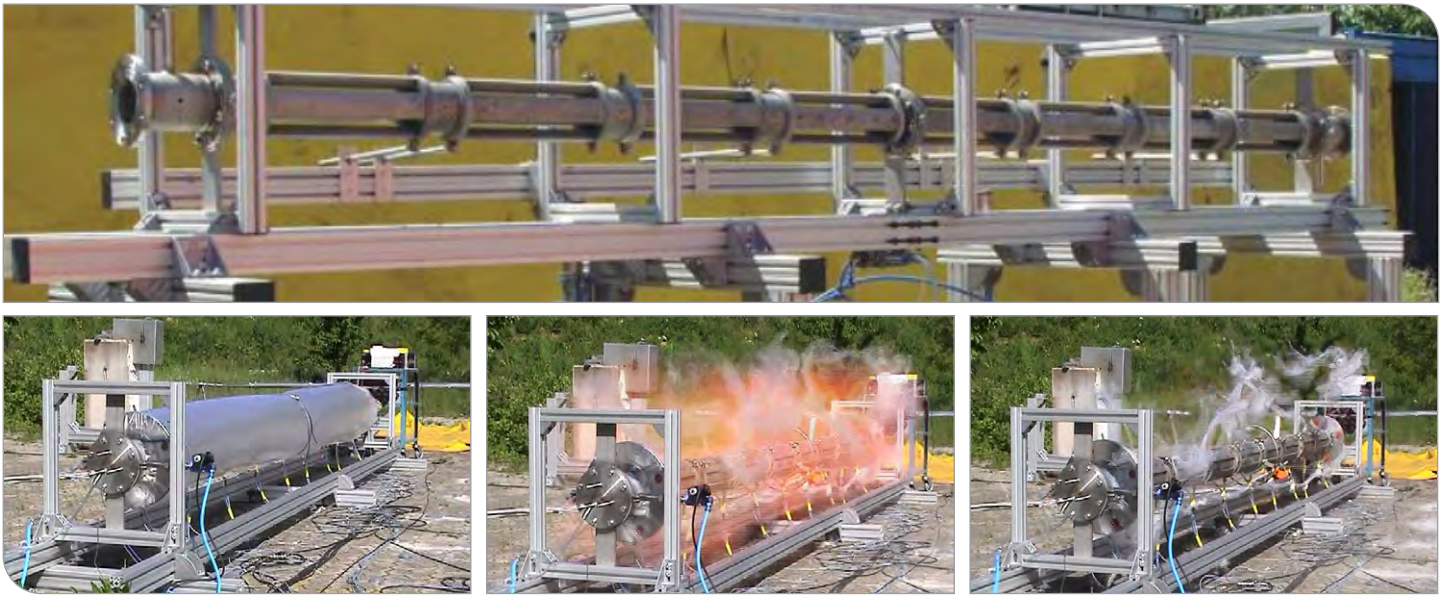
The PET (partially vented explosion tube) is used to study turbulent combustion processes of hydrogen-air mixtures in partially vented geometries. These may be leaky H_2 storage tanks in rooms with doors and windows. Experiments in particular focus on the influence of relief openings on combustion loads.

The experiments are aimed at obtaining a database to derive regulations and standards for the safe operation of hydrogen storage systems, hydrogen-driven vehicles, and the associated equipment and facilities.

Development of the combustion process over time is mainly determined by the interaction of chemical reaction, turbulence, and pressure relief. Combustion loads are reduced by big openings for pressure relief. The test facility shown below allows for the systematic investigation of the influence of locations and sizes of relief openings on the combustion process.

Development of Simulation Programs

In addition to the experiments, ITES develops an ensemble of computer-aided 3D programs for the simulation of hydrogen release and combustion scenarios. The software is used to calculate how hydrogen disperses in closed garages, tunnels, or boiler rooms and how combustion processes take place in case of an ignition. With the help of such numerical simulations, numerous safety situations can be checked and improved specifically without having to conduct expensive experiments in each case.



Experiment with the partially vented explosion tube at KIT.

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Professor Dr.-Ing. Thomas Jordan
Hermann-von-Helmholtz-Platz 1
76344 Eggenstein-Leopoldshafen, Germany
Phone: +49 721 608-26105
Email: thomas.jordan@kit.edu

Karlsruhe Institute of Technology (KIT) · Prof. Dr. Oliver Kraft – Acting President of KIT · Kaiserstraße 12 · 76131 Karlsruhe, Germany

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