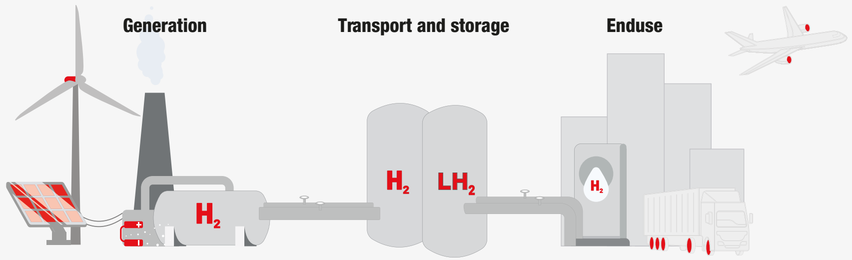
Testing Machines and Testing Systems for:

Hydrogen Technology

ZwickRoell

Hydrogen in materials testing: ZwickRoell solutions for certified safety and reliability.

As an expert in the field of materials testing, ZwickRoell offers you years of experience when it comes to precise and safe testing solutions for applications involving the use of hydrogen. We understand the guidelines of the hydrogen industry and support you in attaining reliable material characteristics with tests under both direct and indirect influence of hydrogen, very high pressure conditions, extremely low temperatures, or tests lasting for extended periods of time.



Electricity generation (wind, solar, nuclear, etc.)

Hydrogen production (electrolyser, steam reformation and cracking, etc.)

Gaseous & Liquid hydrogen (hydrogen tank and pipeline)

Mobility (fuel cell, hydrogen engine, etc.)
Heat & Energy (fuel cell, heat pump, gas and steam turbine, etc.)
Feedstock

Our portfolio includes a wide range of professional solutions along the entire hydrogen value chain: from generation, transport and storage, to user-specific applications. We provide the right solutions to perfectly meet your requirements in the ongoing development of durable and long lasting materials and components. Join us in taking the next step in mechanical materials testing toward a more sustainable future with hydrogen!

160 years

of experience in materials testing.

We implement customer-specific test methods for fluid or gaseous hydrogen.

We implement the corresponding hydrogen handling guidelines in accordance with the standards.

We offer safe and reliable testing solutions along the entire hydrogen value chain.

We promote an ongoing exchange with experts in the field of hydrogen, foster collaborative projects with universities, research institutes and the industrial sector, and are engaged in nationally and internationally renowned hydrogen projects.

>190

worldwide product and industry expert network.

-253 °C

testing in very low temperature conditions (cryogenics).

Electrolyzers and fuel cells: ZwickRoell testing solutions.

Electrolyzers and hydrogen fuel cells are important technologies in the energy sector that offer environmentally friendly and efficient energy sources. While hydrogen fuel cells convert electrical energy into chemical energy, electrolyzers generate electrical energy from chemical energy in the form of hydrogen. Materials testing plays an important role in the development of electrolyzers and fuel cells. It ensures that the materials in these systems meet the specific requirements such as high temperature, chemical reactions and mechanical loads.

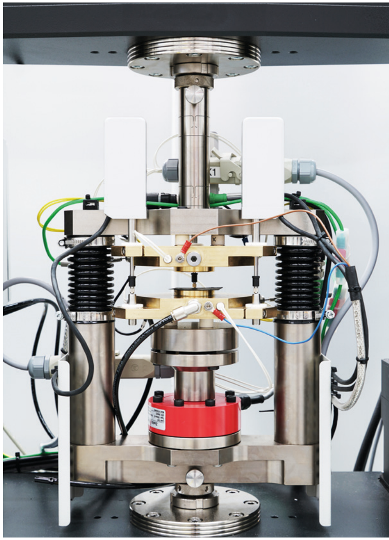
Electrolyzers:

Electrolyzers and hydrogen generators can be scaled for a wide range of application scenarios, from decentralized industrial or commercial plants to large centralized production facilities that can receive hydrogen by truck transportation or connect to pipelines.

Typical electrolyzer technologies:

- Alkaline electrolyzers
- PEM electrolyzers
- SOEC

The improvement of material and component properties for application in electrolyzers is based on a series of innovative methods and manufacturing techniques. First, the mechanical and functional properties of the newly developed or improved materials that form the various cell components must be tested. Tests on the materials and components must be performed as similar to realistic applications as possible to simulate actual working conditions.



Reliable mechanical characteristic values must be determined for every electrolyzer component:

- Membrane electrode assembly (MEA)
- Gas diffusion layers (GDL)
- Bipolar plates (BPP)
- Sealing solutions

ZwickRoell tests and solutions for fuel cells and electrolyzers

	Fuel cells	Electro-lyzers
Tensile test	X	X
Flexure test	X	X
Adhesion test	X	X
Thickness under compression (TUC)	X	X
Electrical resistivity under compression (RUC)	X	X
Permeability under compression (PUC)	X	X
AllroundLine Z010 - for testing the gas diffusion layer: TUC, RUC and PUC.	X	X
testXpert testing software with specially developed program for TUC/RUC/PUC tests.	X	X

Fuel cell:

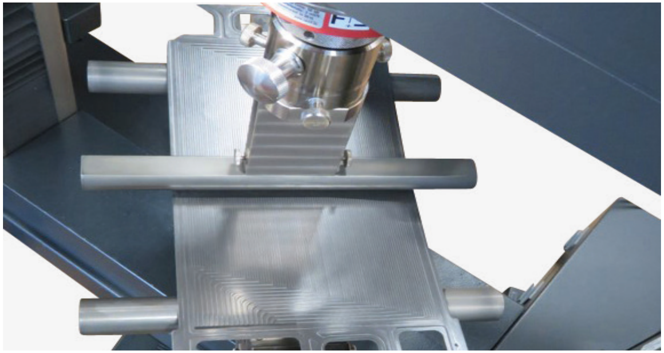
Hydrogen fuel cells are developed for different applications and are used for mobileas well as stationary energy applications.

Typical fuel cell technologies:

- AFC
- PEMFC
- SOFC

To ensure the efficiency, performance and service life of fuel cells, material characterization of components for hydrogen fuel cells is essential. It is important that the materials/ component test is as realistic as possible to simulate actual working conditions. Reliable mechanical characteristic values must be determined for every fuel cell component:

- Membrane electrode assembly (MEA)
- Gas diffusion layers (GDL)
- Bipolar plates (BPP)
- Sealing solutions



Bipolar plate in 3-point flexure test

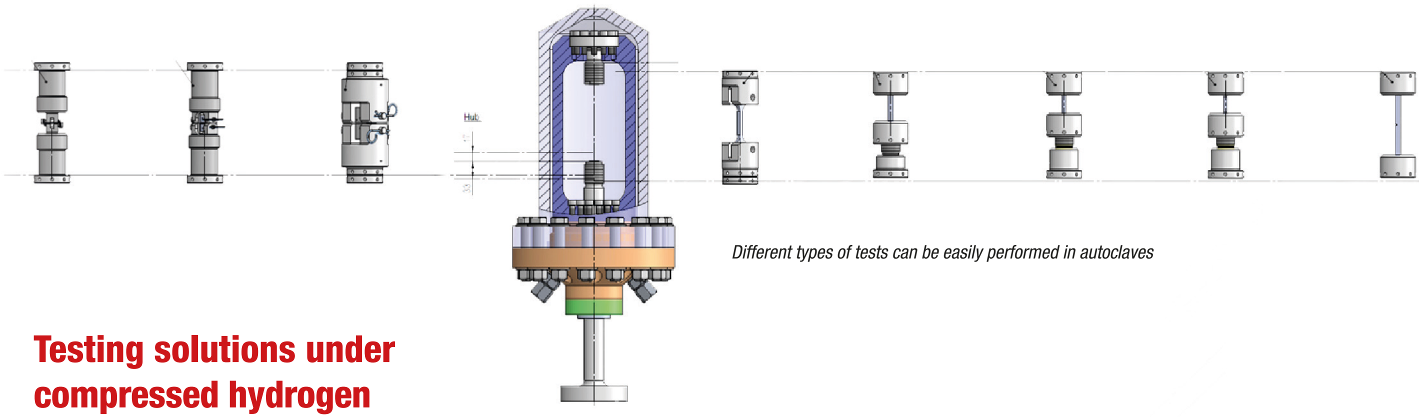
Hydrogen storage and transport.

Efficient storage and transport are critical to ensure optimal use of hydrogen energy. The continuous development of hydrogen technologies also presents new challenges for materials testing. For reliable and safe use of hydrogen energy, extensive materials testing under real-life application conditions is essential.

Gaseous hydrogen can either be transported through pipelines, or it can be compressed before transport and during storage in hydrogen tanks or cylinders. An additional option for the transport of large volumes of hydrogen is in liquid form, for which a temperature of 20 K is required.

TÜV SÜD (Technical Inspection Association) collaboration:

- *Long standing collaboration between ZwickRoell and TÜV SÜD for hydrogen topics.*
- *Knowledge exchange on developments in hydrogen requirements and testing related topics.*
- *Safety-related support in testing machine commissioning by TÜV SÜD.*



Different types of tests can be easily performed in autoclaves

Testing solutions under compressed hydrogen conditions: autoclave

With this testing system, the material is tested in a pressure vessel filled with hydrogen. This vessel is also referred to as autoclave. The hydrogen in the autoclave can, for example, be compressed to 400 bar and penetrates the surface of the specimen. The mechanical properties of the specimen will be tested under the influence of compressed hydrogen.

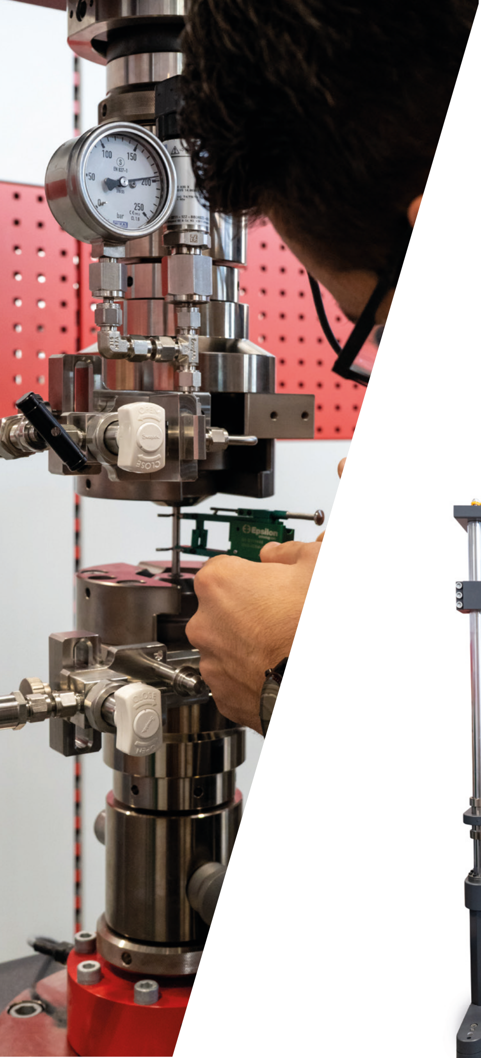
Various applicable standards exist that are used in different industries. For hydrogen piping and pipelines, the American standard ASME B31.12 is most commonly used, while for pressure vessels, the ASME BPVC standard is applied.

Testing in compressed hydrogen tanks or vessels:

- Tensile tests: ISO 6892, ASTM E8
- Slow strain rate test (SSRT): ASTM G129, ASTM G142
- Fracture mechanics test: ASTM E1820, ASTM E399, ISO 12135
- Crack growth test: ASTM E647
- Low cycle fatigue test: ASTM E606, ISO 12106
- High cycle fatigue test (S-N test): ASTM E466, DIN 50100

ZwickRoell uses autoclaves up to a maximum pressure of 400 bar as standard, and up to 1000 bar for special cases.

Because this involves handling a pressure vessel and compressed hydrogen, special safety precautions must taken with which we will gladly assist you with support from TÜV SÜD (Technical Inspection Association).



Testing solutions under compressed hydrogen conditions: hollow specimen.

Low investment and testing costs, fewer safety measures, and easy operation represent the benefits of testing metallic hollow specimens under compressed hydrogen conditions. This method for the qualification of materials under compressed hydrogen is ideal for tensile tests, creep tests and tests with alternating loads.

This is how the hollow specimen method works:

The hollow specimen is filled with hydrogen. The internal pressure can be up to 200 bar. The strain is measured and controlled via an extensometer. To ensure all around safety, ZwickRoell offers a documented safety plan and supports you with the installation process.

Strain measurement on hollow specimen

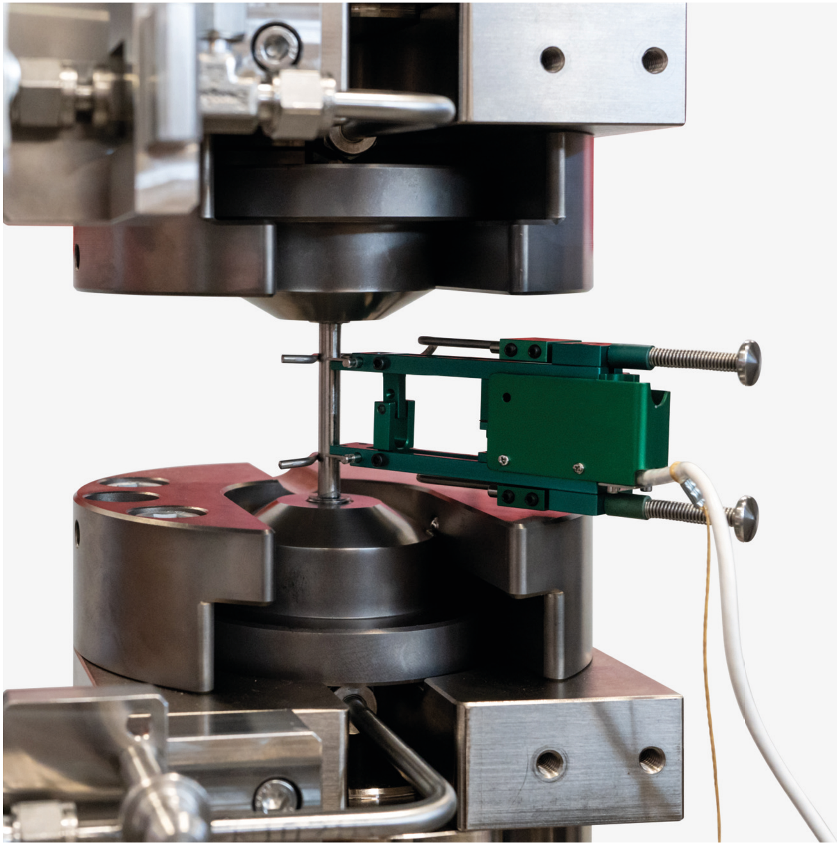
The advantages of hollow specimens:

- Low investment and test costs, and easy operation.
- Specimens can be filled with a wide variety of gases and mixtures, such as hydrogen, natural gas, nitrogen and corrosive gases.
- Less effort in terms of safety, since the method can be implemented in a normal laboratory environment.
- ZwickRoell testing machines can be retrofitted for the hollow specimen method.

ZwickRoell collaboration in TransHyDE research project

The development of the method incorporates the results of initiatives and projects related to hydrogen, in which ZwickRoell is involved:

- *The TransHyDE project of the German Federal Ministry of Education and Research (BMBF) focuses on creating the basis for standardization for testing hollow specimens.*
- *We are directly involved in the TransHyDE – H2 Transport project, which centers around the development and evaluation of different technologies for hydrogen transport.*
- *We are actively participating in developing the definition of the international test standard ISO/TC 164/SC 1/WG9 in the TransHyDE – H2 Transport associated sub-project H2 HollowTensile (H2HohlZug), which addresses the standardization of hollow tensile specimen technology.*



Hollow specimen with clip-on extensometer

Cryogenics: testing with safety and reliability at cryogenic temperatures.

ZwickRoell offers a wide range of testing solutions for flexure, compression, tensile or shear tests at temperatures of 20 K (-253 °C) for reliable results and maximum safety. To test materials at cryogenic temperatures and determine their fatigue and fracture mechanical behavior, our machines have a maximum load capacity of 100 kN.

Option 1: Cooling with a temperature chamber
Temperature chambers are ideal for tests at elevated temperatures as well as low temperatures down to approximately -170 °C. In this case, the temperature depends on the cooled volume in the chamber as well as the volume of the test rods that extend into the temperature chamber.

Option 2: Cooling with a nitrogen immersion cryostat
For nitrogen immersion cryostats, the specimen is immersed in a nitrogen bath. The test temperature range of immersion cryostats is reduced to the temperature of liquid nitrogen. The specimens, along with the specimen grips, are guided into the immersion cryostat from above using a self-contained yoke.

Option 3: Cooling with nitrogen and helium in a continuous flow cryostat
Nitrogen and helium continuous flow cryostats are operated in a range of ambient temperature to low temperatures of approximately 20 K (-253 °C), depending on the cooling medium. As soon as the lowest possible temperature of the nitrogen is reached, it is cooled with helium from a Dewar vessel until the final temperature is reached.

Testing machine for static tests

Immersion cryostat with view window

Cooling down with liquid nitrogen

Hydrogen embrittlement: test method for measurement of hydrogen embrittlement threshold of metallic materials to ASTM F1624 and ASTM F519.

ZwickRoell offers two test methods to determine the influence of hydrogen on metals. These are described in standards ASTM F1624 and ASTM F519.

The test method according to ASTM F1624.
ASTM F1624 describes an accelerated test method (tensile or flexural loading) to determine the susceptibility of steels to time-delayed failure such as that caused by hydrogen. The test is either performed in air or in a controlled environment to measure if there is residual hydrogen in the steel from processing.

The test method according to ASTM F519.
ASTM F519 describes a mechanical test method (tensile or flexural loading). It defines acceptance criteria for coating and plating processes that can lead to hydrogen embrittlement in steels.

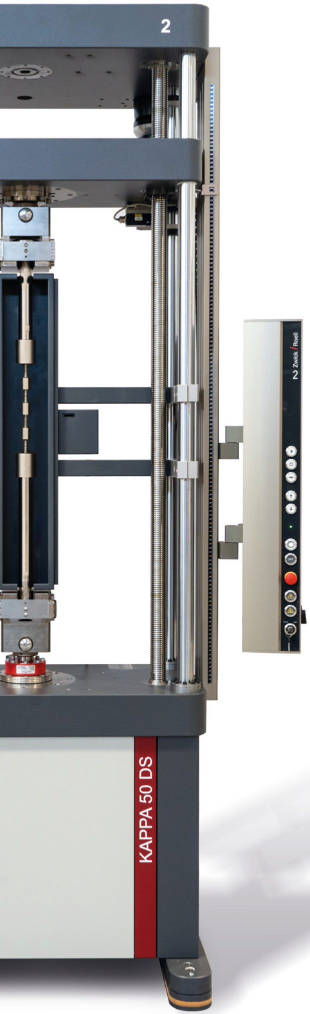
Specimen types according to ASTM F1624:

- *CT specimens according to ASTM E399*
- *Notched specimens according to ASTM F519*

Specimen types according to ASTM F519:

- *Type 1: notched specimens*
- *Type 1a: notched, round, tensile load*
- *Type 1a.1: standard size*
- *Type 1a. 2: oversized*
- *Type 1b: notched, round, tensile*
- *Type 1c: notched, round, flexure*
- *Type 1d: notched, C-ring, flexure*
- *Type 1e: notched, square, flexure*
- *Type 2: unnotched specimens*
- *Type 2a: O-ring, flexure*

Creep testing machine with test equipment according to ASTM F1624



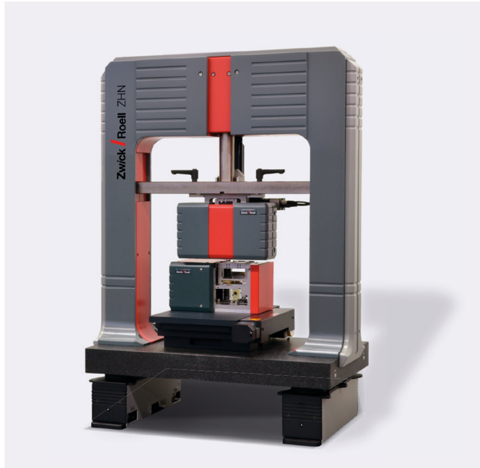
The hardness testing solution for hydrogen embrittlement.

Hardness testing is a common method to test the influence hydrogen on materials.

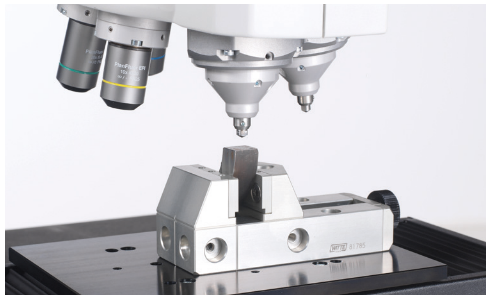
Nanoindentation:
For microstructural characterization of hydrogen-preloaded or in-situ testing of materials and components, we offer a solution with the ZHN. This can also be integrated with a scanning electron microscope and helps, for example, to inspect seals, pipeline or cylinder materials and components.

Micro hardness test:
To investigate the influence of welding process parameters on susceptibility to hydrogen embrittlement of welded joints (on pipelines, cylinders, valves, car bodies), we offer the DuraScan. For example, the hydrogen distribution in metals can be quantitatively determined on WOL (wedge opening loaded) specimens.

Universal hardness testing:
To test various machine elements, such as connectors that are potentially susceptible to hydrogen embrittlement when its hardness values greater than 320 (HV). The findings support, for example, the development of effective pickling additives for galvanization process of high-quality machine elements.

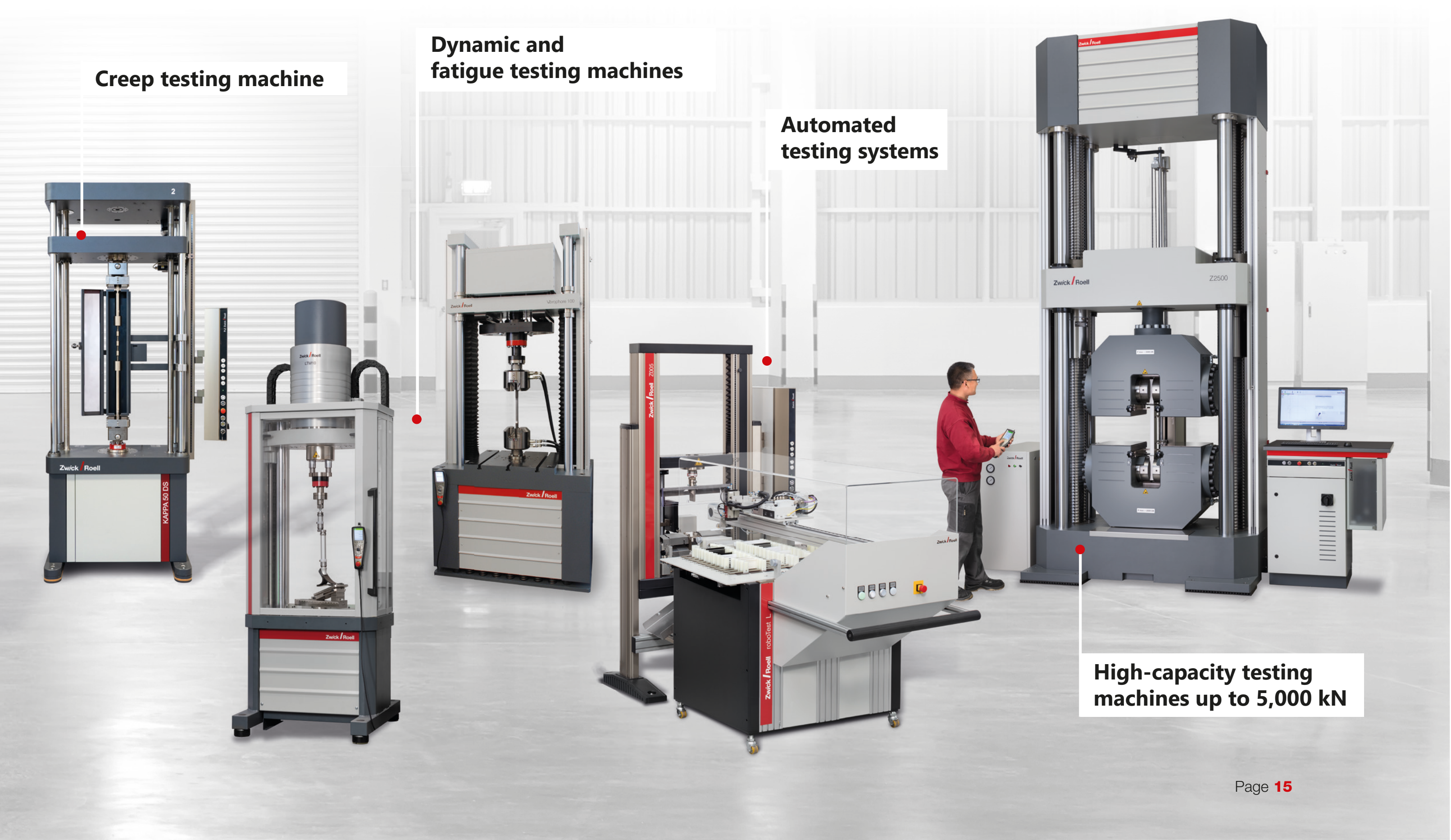


ZHN nanoindenter for testing of metals



Vickers hardness tester: the turret adapts to different test methods

The right solution for any test requirement.


Creep testing machine
Dynamic and
fatigue testing machines
Automated
testing systems
High-capacity testing
machines up to 5,000 kN

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