

Hydrogen is the Future.
We're Already There.

AiP

Mastering Hydrogen Testing

With High-End-Testrigs from AiP



Hydrogen

technologies such as **fuel cells** and **electrolyzers** play a pivotal role in achieving carbon-neutral mobility and sustainable energy storage solutions. As these technologies advance, reliable and reproducible testing becomes essential - not only for complete systems but also for individual **stacks**, **cells**, and Balance of Plant (BoP) **components**.

AIP addresses these challenges with modular, self-sufficient, and highly flexible hydrogen test benches designed to cover a wide range of development scenarios. Our solutions enable precise control of operating conditions, dynamic media supply, and integration of advanced automation strategies. Combined with our in-house developed AIP-MCS Hydrogen PlugIn, we provide a unified automation platform for all hydrogen test benches, ensuring safety, scalability, and real-time data acquisition.

Whether you are testing **Fuel Cell Membrane Electrode Assemblies (MEA)**, full stacks, or electrolyzer systems, AIP delivers tailored solutions that accelerate development and guarantee compliance with international standards. With our modular approach, customers can adapt their test setups to evolving requirements—future-proofing their investment in hydrogen technology.

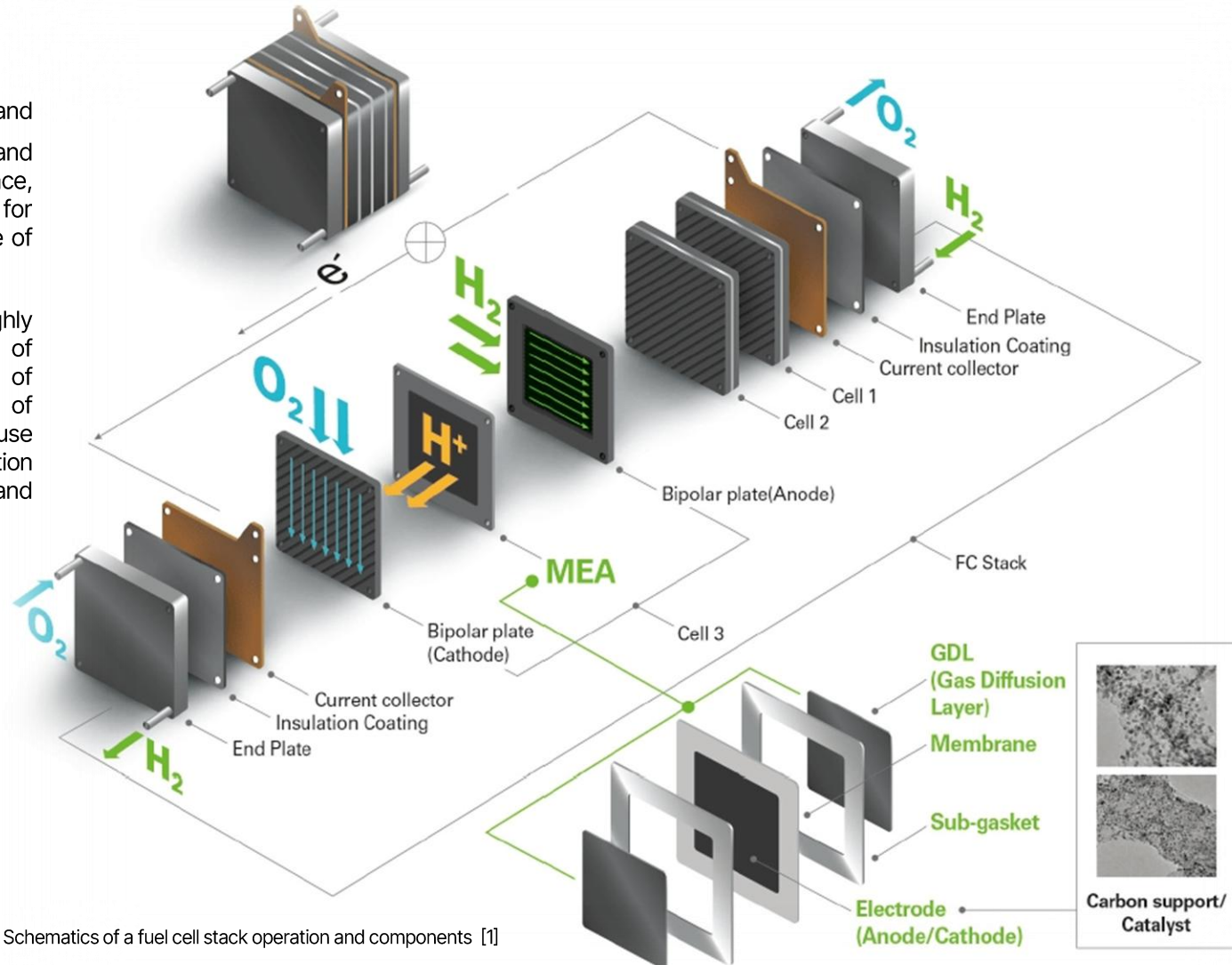


Fig.: Schematics of a fuel cell stack operation and components [1]

[1] Sutharssan, T., Montalvao, D., Chen, Y. K., Wang, W. C., Pisac, C., & Elemara, H. (2017). A review on prognostics and health monitoring of proton exchange membrane fuel cell. Renewable and Sustainable Energy Reviews, 75, 440-450.

AiP Hydrogen Testing Portfolio Overview

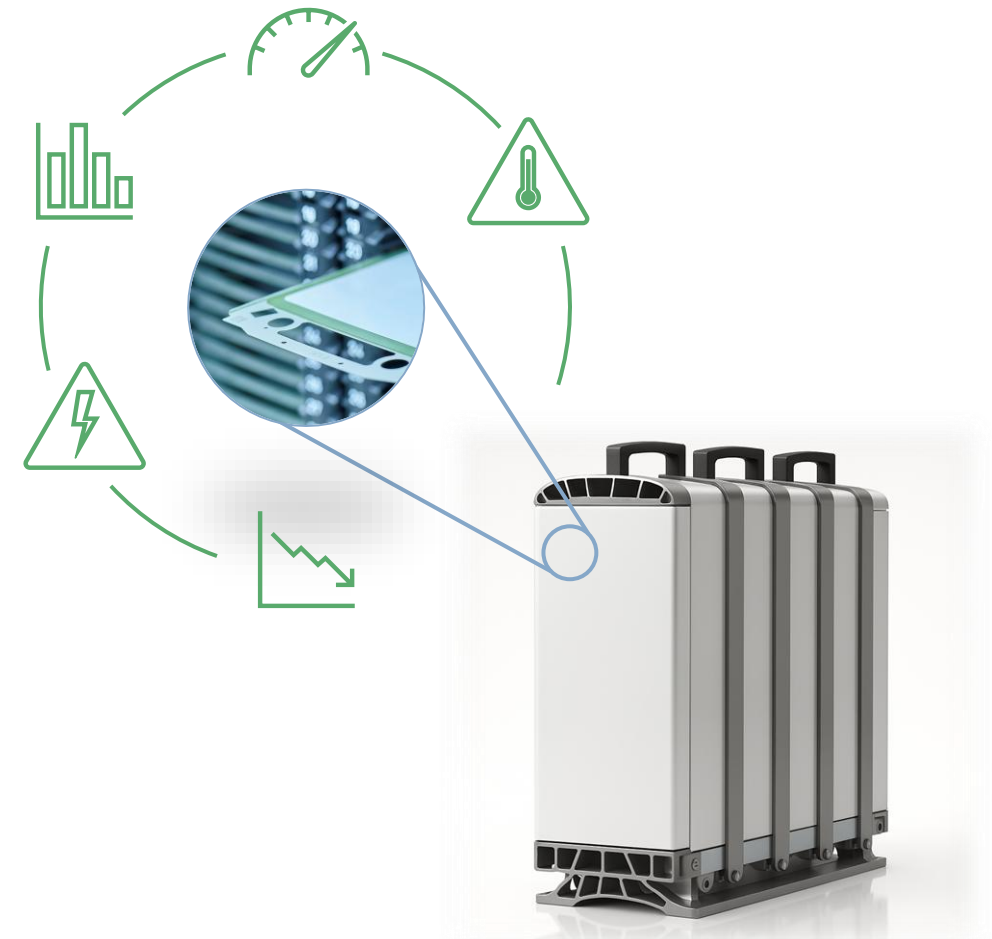
Our hydrogen testing solutions cover the entire development chain—from single-cell characterization to full system validation. The modular design ensures maximum flexibility and scalability for diverse applications.

Fuel Cell Testing

- Membrane Electrode Assemblies (H2FC-MEA)
Precise characterization of electrochemical performance under controlled conditions.
- Fuel Cell Stacks & Systems (H2FC-STACK / H2FC-SYSTEM)
Dynamic testing for durability, efficiency, and real-world load profiles.

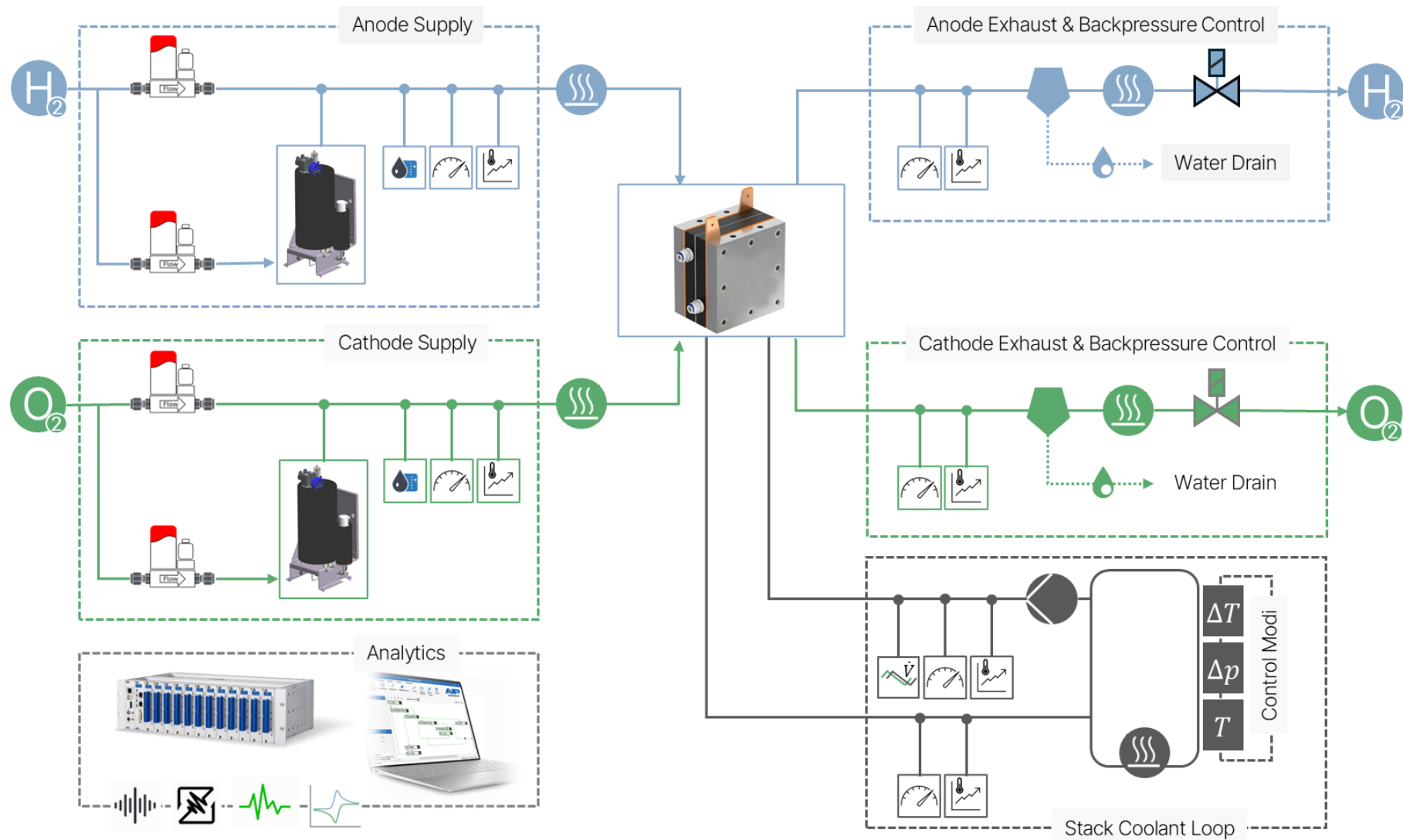
Electrolyzer Testing

- Electrolyzer Cells & Stacks (H2EC)
High-accuracy testing for hydrogen production efficiency and operational stability.



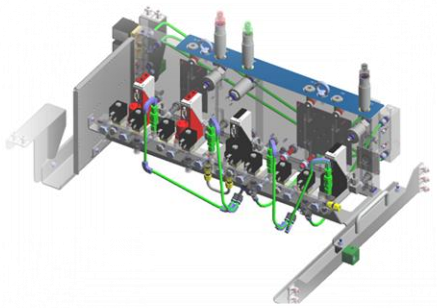
The AIP Solution

H₂FC - P&ID Diagram



The AIP Solution

H₂FC – Functional Groups



H₂FC – Valve Matrix

Precise Gas Management for Fuel Cell Testing

Our valve matrix ensures accurate gas dosing via high-performance mass flow controllers for both anode (H₂) and cathode (air).

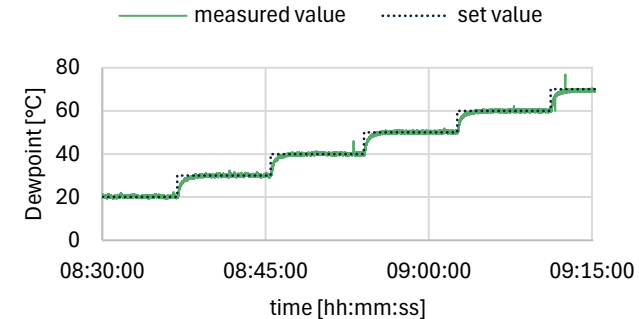
- Fast dew point regulation through adiabatic mixing of dry and wet gases (100% r.H.)
- Integrated calibration line for maximum reliability
- Accuracy: ±0.5% of measured value; ±0.1% of full scale
- Additional MFCs for N₂ (anode), O₂ (cathode), and contamination gases

H₂FC – Humidification

Flexible Humidification Solutions for Every Power Range

Choose between bubble column reactors (up to 5 kW), humidifier columns, or electric steam boilers (up to 580 kW or more).

- Dew point control accuracy: ±1 °C
- Operating temperatures up to 90 °C (higher optional)
- Designed for dynamic and stable humidification under real-world conditions

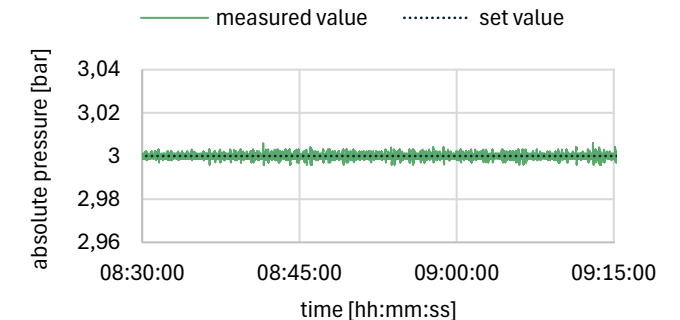
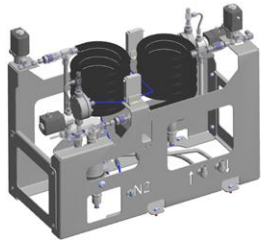


H₂FC – Exhaust

Safe and Efficient Exhaust Handling

Our exhaust system guarantees precise pressure control and automatic condensate management.

- Automatic drain of condensate trap with sampling option
- Highly dynamic downstream pressure regulation
- Supports dead-end and purge operations for flexible testing scenarios



The AIP Solution

H₂EC – Functional Groups

Flexible and Safe Testing for PEM and AEM Electrolyzers

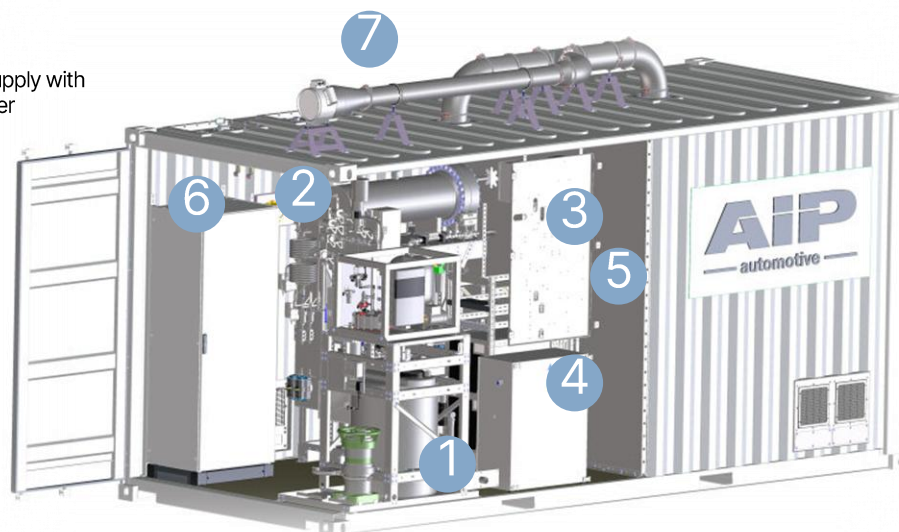
The AIP H₂EC system is designed for precise testing and characterization of PEM and AEM electrolyzer cells and stacks under defined operating conditions. Built on a modular, self-sufficient concept, the H₂EC offers maximum flexibility for research, validation, and long-duration endurance testing.

Test sequences are parameterized via an intuitive sequence editor and executed directly on the real-time computer (AIP RTCU), ensuring uninterrupted operation and data recording, even for very long test cycles. The system is operated through the MCS automation platform, featuring a user-friendly graphical interface with online measurement display, sequence editing, and monitoring capabilities.



Standard Features

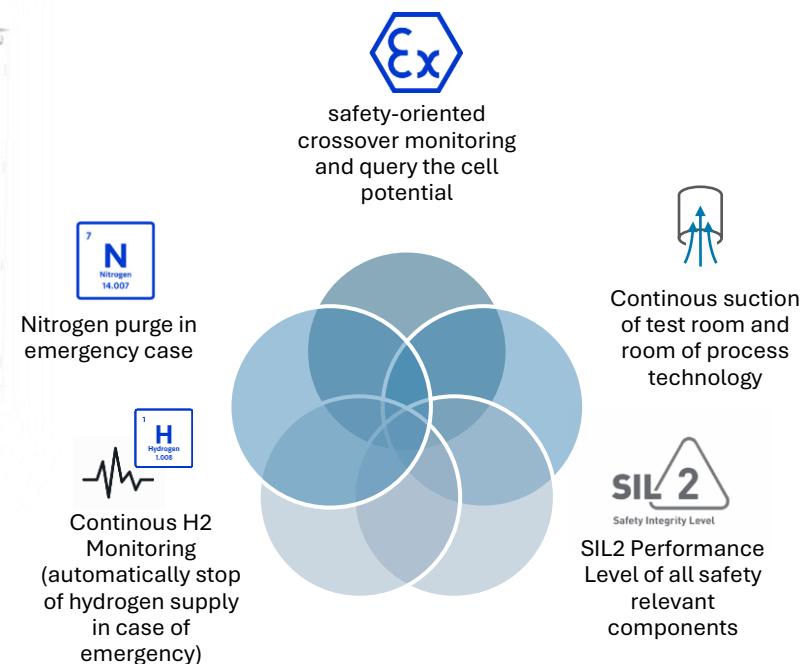
- 1 Pressurized DI water supply with integrated ion exchanger
- 2 Adjustable pressure and temperature at anode and cathode
- 3 Precise gas flow measurement for H₂ and O₂
- 4 Programmable Regenerative DC Source Sink
- 5 Highly accurate DAQ System incl. EIS



- 6 Comprehensive monitoring and plausibility checks
Fully automated, unmanned operation with data logging and export
- 7 ATEX exhaust air system connection option

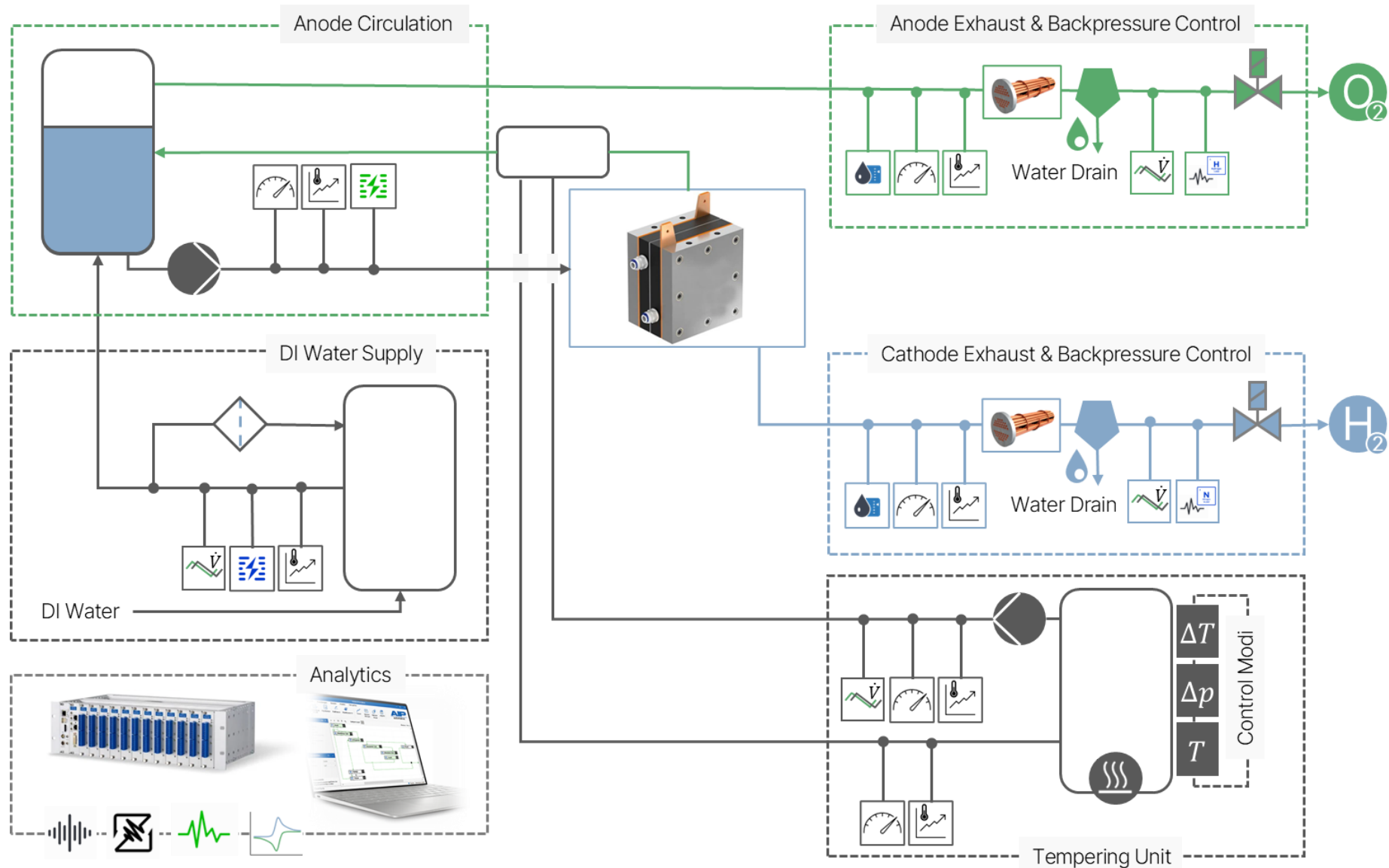
Safety Concept

The H₂EC safety architecture is designed according to Directive 1999/92/EC to prevent explosive atmospheres during hydrogen operation. It includes detection, assessment, and elimination of ignition sources, ensuring compliance and maximum operator safety.



The AIP Solution

H₂EC – P&ID Diagram



Analytics

EIS - Electrochemical Impedance Spectroscopy

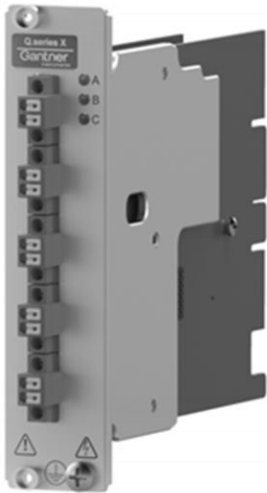


Why Electrochemical Impedance Spectroscopy (EIS)?

The rapid transition toward hydrogen-based energy systems and electrification demands a deeper understanding of electrochemical components such as fuel cells and electrolyzers. To maximize **efficiency**, **durability**, and **safety**, these systems must be analyzed beyond conventional voltage and current measurements.

EIS provides this level of insight. By measuring the **frequency-dependent** internal **resistance** of cells and stacks, EIS enables developers to **detect degradation** effects early, **identify failure modes**, and evaluate the **state of health** under real operating conditions. This detailed analysis is essential throughout all development stages ensuring optimized performance and extended lifetime of hydrogen technologies.

With EIS integrated into AIP test benches, you gain a powerful tool for accelerating innovation and securing reliable results for tomorrow’s hydrogen economy.



Benefits of AIP EIS Integration



Modular architecture for easy adaptation to different test scenarios



Seamless integration with AIP-MCS automation platform



Compliance with international standards for hydrogen testing

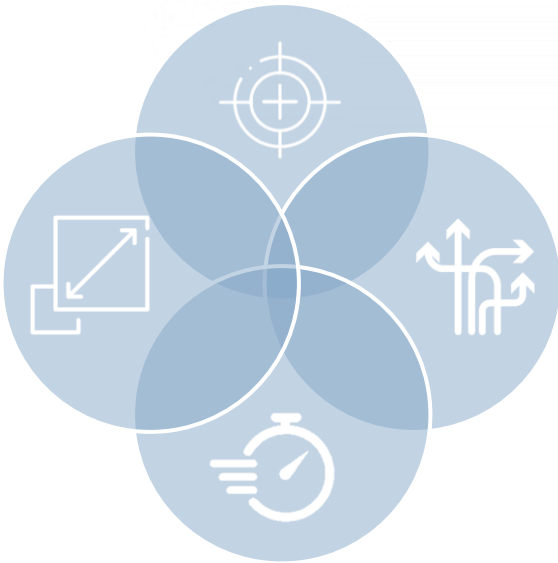
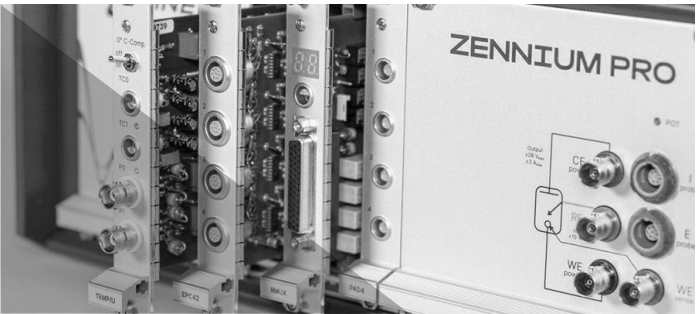
Technical Specification

ZAHNER

DC voltage ranges: ± 5 V and ± 15 V
Current up to ± 3 A over 12 current ranges
EIS frequency range from 10 μ Hz to 8 MHz
For low current range

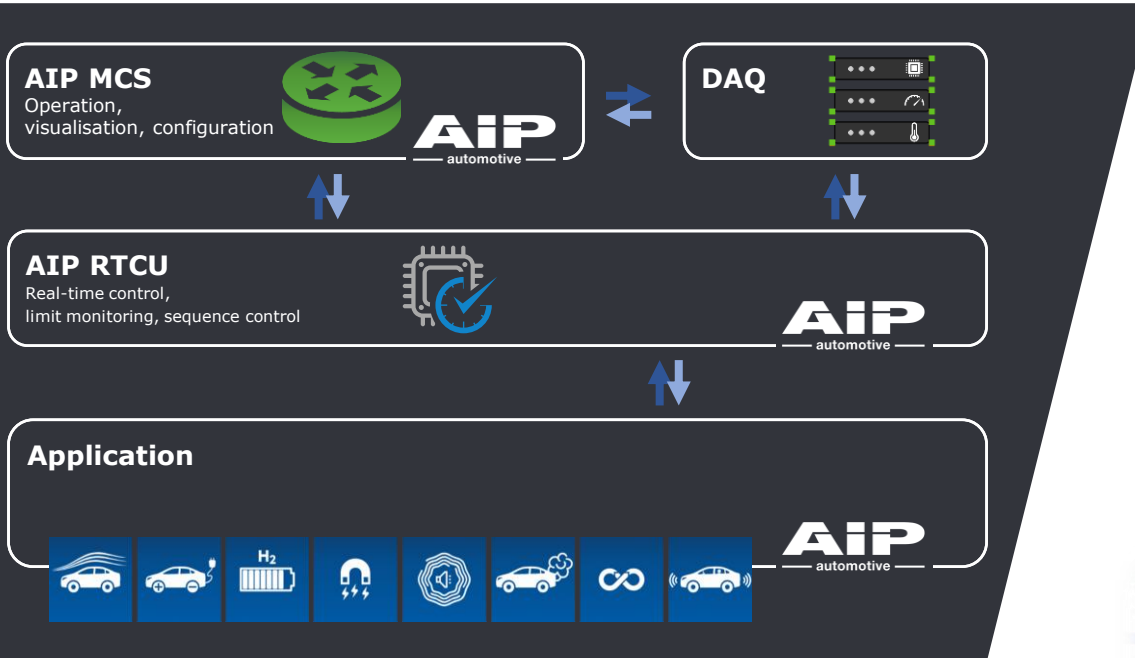
Gantner
instruments

DC voltage ranges: ± 5 V
EIS frequency range from 0,1 Hz to 10 kHz
For high current range
Multichannel EIS



Automation

MCS – Hydrogen PlugIn



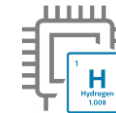
Key Features

- Real-Time Control: Deterministic hardware for dynamic processes
- Scalable Architecture: From single-cell setups to full-stack systems
- Open Interfaces: EtherCAT, CAN, Ethernet and many others
- User-Friendly: Modern UI for fast configuration and monitoring

AIP Automation Platform

Complex Test Processes Made Simple

With the combination of **AIP MCS** and **AIP RTCU**, you can automate your hydrogen test benches holistically, efficiently, and future-proof. Our platform unites data acquisition, real-time control, and centralized process management in one open, scalable system.



MCS Hydrogen PlugIn

Specialized Functionality for Hydrogen Testing

The MCS Hydrogen PlugIn extends the AIP automation platform with dedicated features for hydrogen applications. It provides advanced control strategies and safety mechanisms as well as Test Sequence Sets tailored to the unique requirements of fuel cell and electrolyzer testing.



Key capabilities include:

- Integrated valve matrix control for precise gas dosing
- Humidification and exhaust management with dynamic dew point and pressure control
- Safety functions such as leak detection, purge operations, and emergency shutdown
- Support for complex hydrogen-specific test profiles and conditioning sequences via graphical sequencer
- Dataprocessing toolbox

H₂ ready

Solutions for hydrogen-powered vehicles

Hydrogen-Capable Vehicle Test Benches

AiP offers a broad portfolio of chassis dynamometers, vehicle and powertrain test benches, now fully adapted for hydrogen-powered applications. From passenger cars to heavy-duty vehicles, we provide solutions that combine performance, safety, and flexibility. Our hydrogen-capable systems include climatic altitude chambers, EMC chassis dynamometers, and integrated safety concepts for operation and refueling inside test facilities.

These test benches are designed to meet the unique challenges of hydrogen propulsion, ensuring compliance with ATEX standards and delivering maximum operator safety. Whether for R&D, certification, or durability testing, AiP enables future-proof testing for zero-emission vehicles.



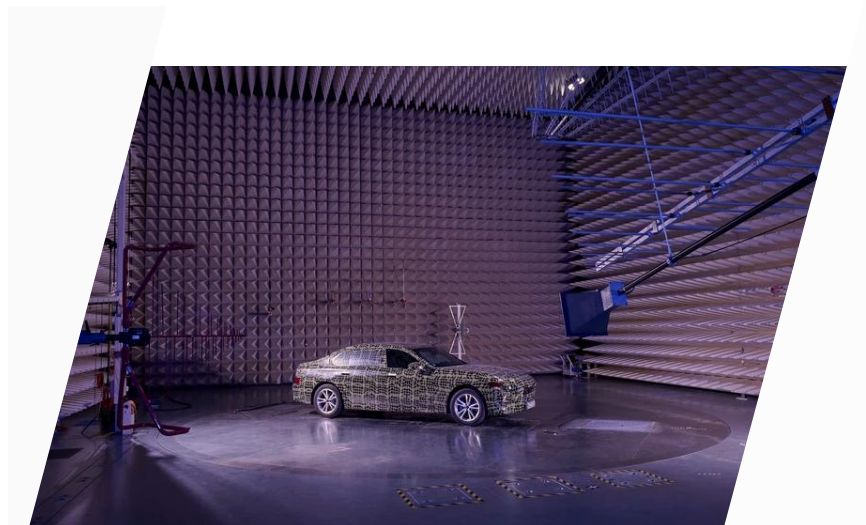
Challenges for Hydrogen Vehicles

- Risk analysis of technical, organizational, and personal measures
- Hydrogen escape during operation or refueling
- Ignition range of H₂ in air: 4–75 vol%



Safety Concept

- Gas detection and leak monitoring
- Air purge with supply and exhaust system
- ATEX-compliant component selection
- Certified safety concept tailored to customer requirements





Your path to Hydrogen testing

measured, validated, secured.



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