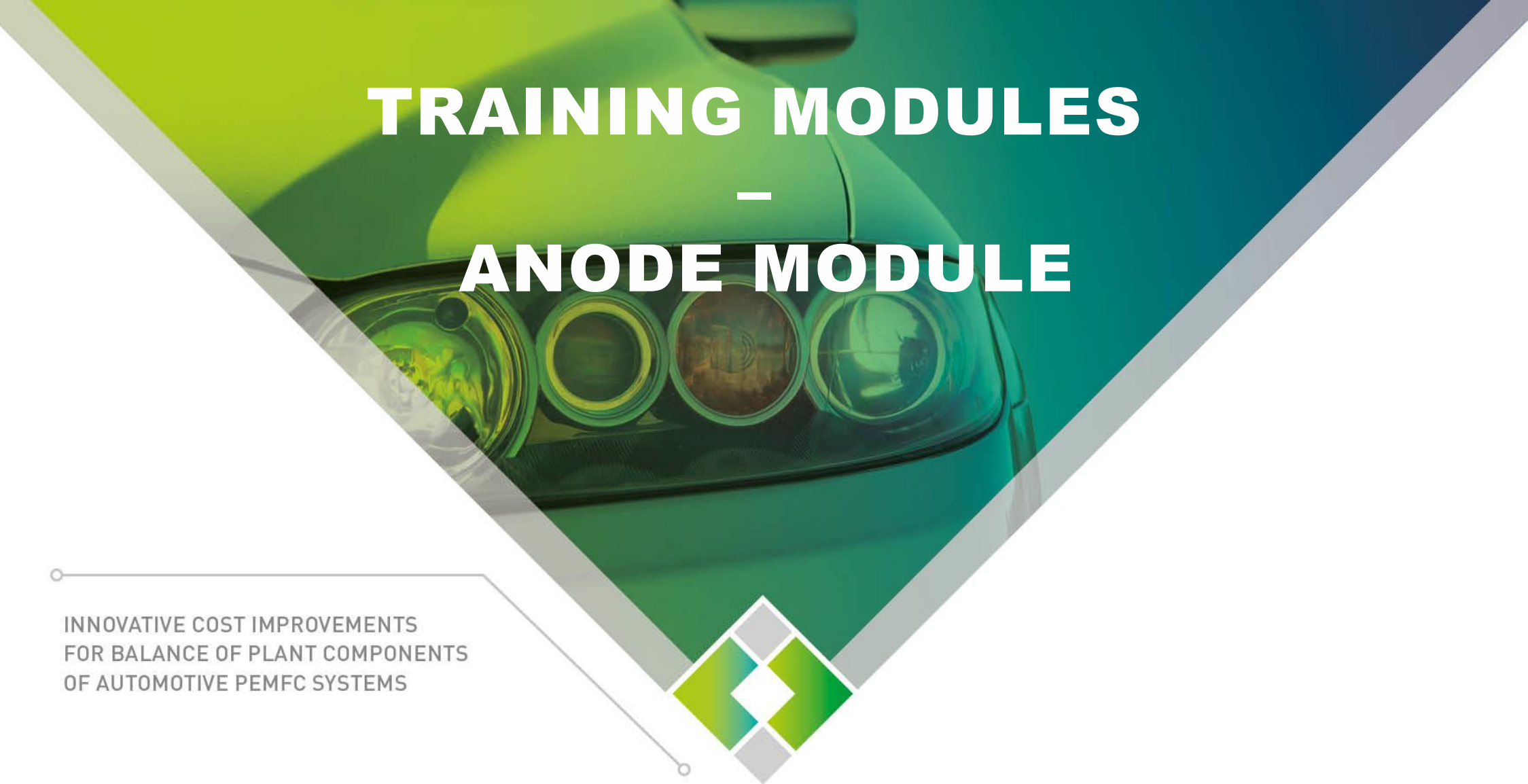

TRAINING MODULES
–
ANODE MODULE

INNOVATIVE COST IMPROVEMENTS
FOR BALANCE OF PLANT COMPONENTS
OF AUTOMOTIVE PEMFC SYSTEMS

INN·BALANCE
AUTOMOTIVE FUEL CELL

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1. PARTNERS ROLE

AVL List GmbH

- Development and optimization of the anode module's design based on CFD and CAD simulation studies
- Selection and procurement of the valves and sensors, manufacturing of components such as the injector/ejector
- Component assembling and testing
- Validation of the functionalities of the anode module

PowerCell Sweden AB

- Definition of the FC stack requirements in terms of operating temperatures and pressures, tolerable amount of inert gases
- Contribution to the design optimization

2. MAIN FUNCTIONS OF THE ANODE MODULE

Prime function

- Provide the needed amount of hydrogen to the fuel cell stack. To avoid fuel starvation in the stack during operation, which is detrimental to the fuel cell stack lifetime, an excess of hydrogen is supplied to the stack. The unused hydrogen that exits the stack should be recovered and recirculated to increase the hydrogen utilization rate of the FC system. The recirculation can either be carried out actively by means of a hydrogen blower or passively by means of an ejector, a jet pump based on the Venturi principle.

Secondary functions

- Preheating of hydrogen to stack inlet temperature
- Monitoring and control: temperature and pressure sensors
- Protection against intermediate hydrogen supply pressure when the system is shut down, pressure relief in case of malfunction of the injection valve
- Removal of water: removal of water droplets from the circulated hydrogen stream, detection of the water level in the water separator and removal of collected water
- Removal of nitrogen: flushing of the anode during start-up and removal of accumulated nitrogen during operation

3. ANODE MODULE COMPONENTS (WITH PASSIVE RECIRCULATION)

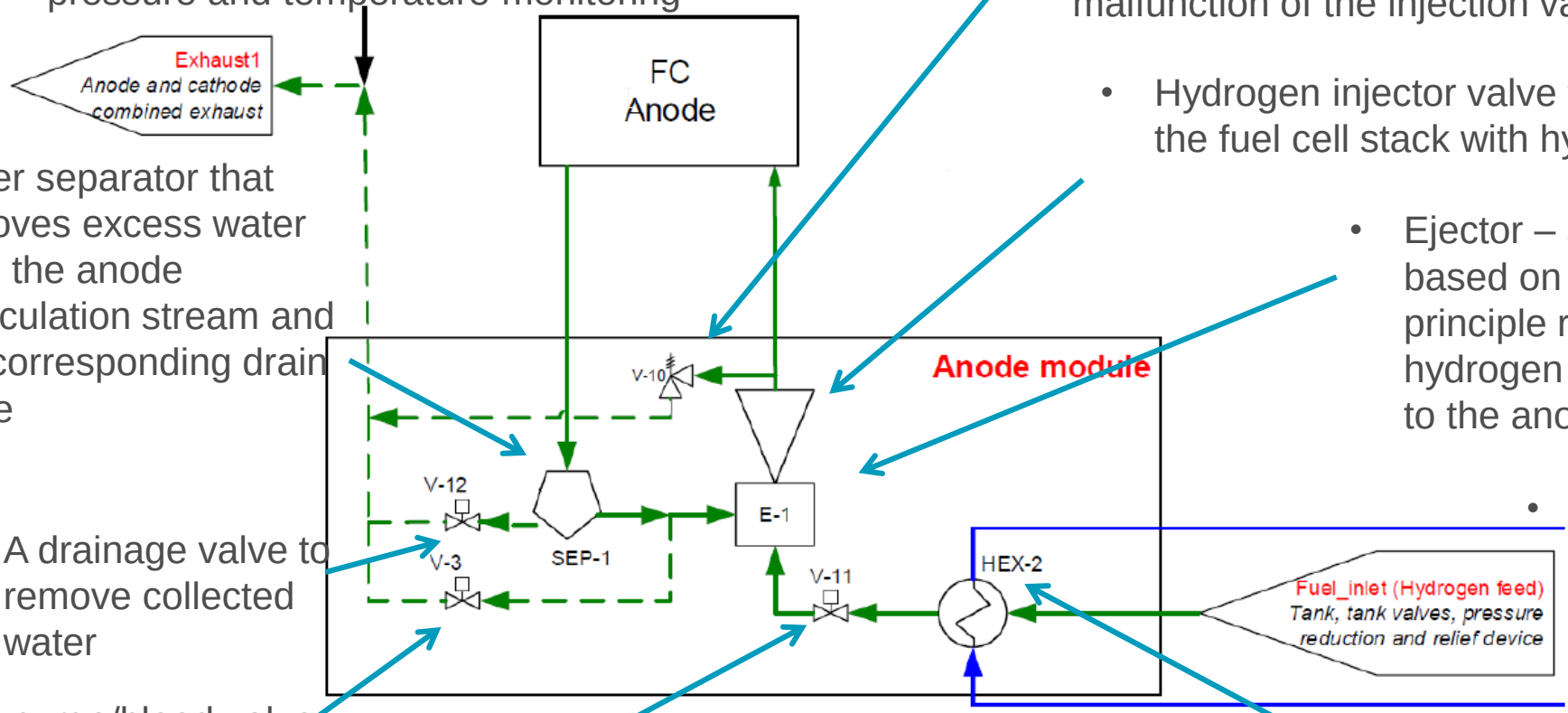
- Necessary sensors technology for pressure and temperature monitoring

- A pressure relief device in case of malfunction of the injection valve

- Hydrogen injector valve that supplies the fuel cell stack with hydrogen

- Water separator that removes excess water from the anode recirculation stream and the corresponding drain valve

- Ejector – a jet pump based on the Venturi principle recycling exhaust hydrogen and fed it back to the anode inlet



- One or more hydrogen tanks at 700 bars

- A drainage valve to remove collected water

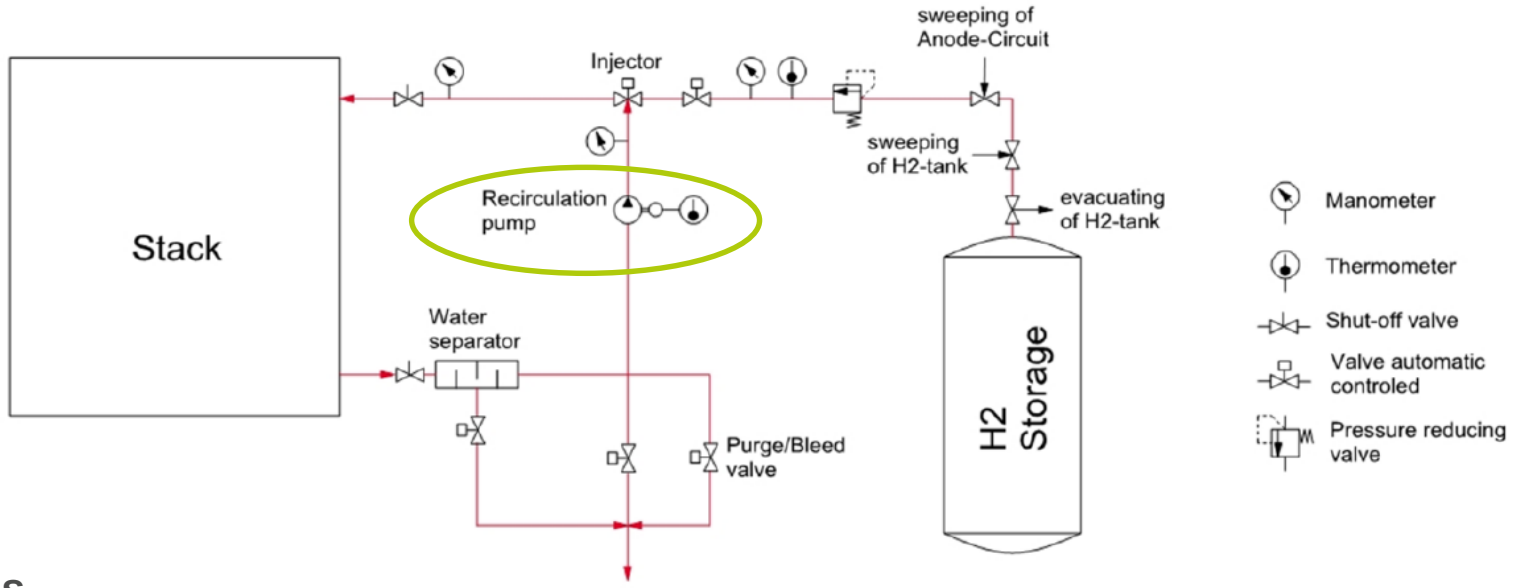
- A purge/bleed valve that is use to remove inert gases and flush the anode during start-up

- Cut-off valves that protects the fuel cell stack from intermediate hydrogen supply pressure when system is down

- A heat exchanger to reach the required hydrogen temperature at the stack inlet

4. PROS/CONS ACTIVE VS. PASSIVE RECIRCULATION SYSTEM

Active recirculation system with pump



Advantages

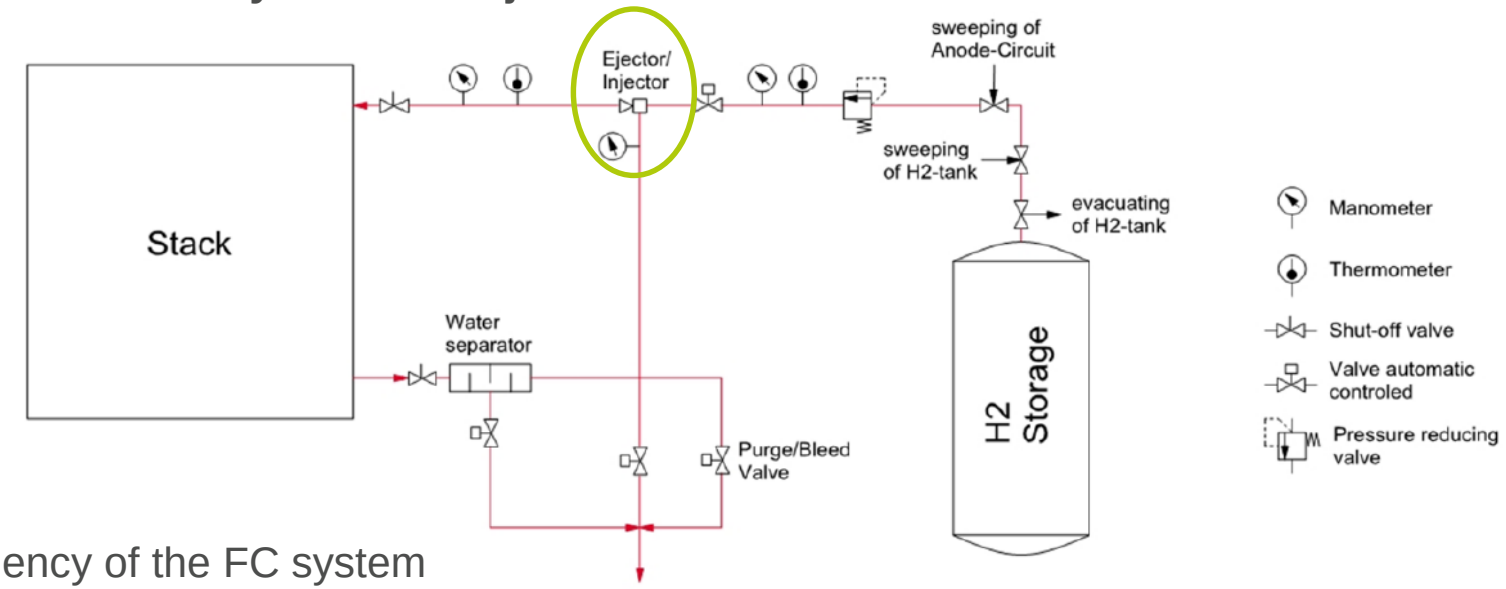
- the hydrogen return rate can be precisely regulated and adapted to the respective operating point
- Can be used in any automotive fuel cell system

Disadvantages

- the component lowers the overall efficiency of the fuel cell system by additional parasitic energy demand

4. PROS/CONS ACTIVE VS. PASSIVE RECIRCULATION SYSTEM

Passive recirculation system with ejector



Advantages

- High efficiency of the FC system

Disadvantages

- the hydrogen recirculation rate can only be determined with the geometry of the Venturi nozzle.
- the injector/ejector solution has to be adapted specifically to the fuel cell stack and the available packaging space, thus an individual engineering solution has to be developed each time.

In line with the objective of 5% increase in efficiency of the fuel cell system, the INN-BALANCE consortium decided to develop an anode module with a passive recirculation system based on an ejector

5. SPECIFIC CHALLENGES RELATED TO THE DESIGN PROCESS

Ejector geometry

- The varying operating points bear the biggest challenge in designing an anode module using a passive recirculation system. It is important to identify an ejector geometry that allows to maintain a hydrogen recirculation at all operating points

Precise calibration of the anode module and design of the water separator to effectively remove accumulating nitrogen and water

- To reduce the nitrogen concentration in the anode module, the closed anode loops need to be opened to release nitrogen. At higher loads, higher mass flow are required an increased opening frequency is required. To minimize the loss of hydrogen, the system must be precisely calibrated
- Water also accumulates in the fuel cell stack and liquid water droplets must be removed from the recirculation stream by using a water separator. However, the water separator causes pressure drops and a balance has to be found between maintaining pressure and eliminating water droplets in the anode module

Compactness and compatibility with conventional manufacturing

- The anode module must be of reduced weight and volume to allow for a better integration and simplified thermal management. Furthermore, the design of the anode module must be optimized in such a way to reduce the part count and the corresponding assembly time, thus mitigating the risk of hydrogen leakage and make it more suitable for series production

6. MAIN DEVELOPMENT STEPS

Steps taken during the development of the anode module

1. Choice of the recirculation system: in line with the objective of 5% increase in efficiency of the fuel cell system, the INN-BALANCE consortium decided to develop an anode module with a passive recirculation system based on an ejector
2. First design of the components by AVL
3. Improvement of the design and packaging size based on feedback from PowerCell
4. Redesign of the stack pod (stack adapter plate) by PowerCell to allow for a better integration of the anode module components
5. 3D CFD simulations by AVL to further optimize the design of the anode module. Simulation results showed that the size of the water separator could be significantly reduced. In order to save place, some components were directly integrated in the stack pod
6. Final adjustments were made after discussions with PowerCell, leading to the final design of the anode module