TRAINING MODULES
–
THERMAL MANAGEMENT SYSTEM

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

INN·BALANCE
AUTOMOTIVE FUEL CELL

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1. PARTNERS ROLE

DLR e.V.

- Design and development of the thermal management concept and control scheme
- Development of an optimal procedure to start the fuel cell system at temperatures below 0°C
- Development of a dedicated test bed to test a new concept for freeze conditioning based on the use of methanol as anti-freeze liquid for flooding of the anode and cathode compartments
- Testing and evaluation of the thermal system

BROSE Fahrzeugteile GmbH & Co. KG

- Development of simulation models for the cooling circuits
- Development of a low temperature circuit concept that minimizes the system components and improves the system efficiency
- Manufactured-oriented redesign of the thermal module

PowerCell Sweden AB and China Euro Vehicle Technology AB

- Specifications regarding fuel cell and vehicle integration provided respectively by PowerCell and CEVT

2. MAIN FUNCTIONS OF THE THERMAL MANAGEMENT SYSTEM

Prime function

- The cooling module keeps all components of the fuel cell systems at a desired temperature level. In normal operation, excess heat must be removed from the fuel cell stack, the fuel cell DC/DC converter, the compressor and the compressor electronics. The compressed cathode gas must be cooled in the intercooler located between the compressor and humidifier and the anode feed gas must be heated to the fuel cell stack operating temperature.

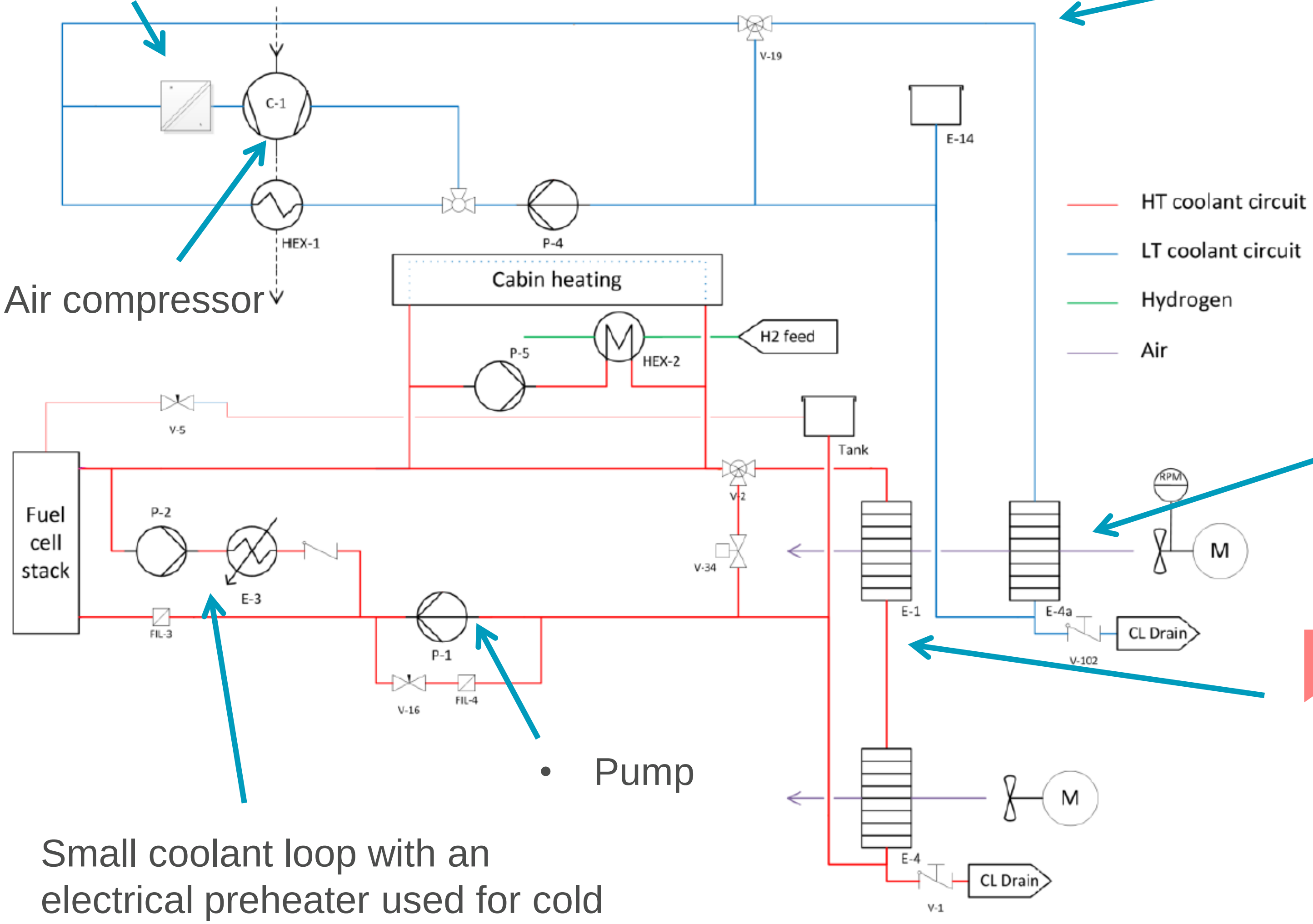
Secondary functions

- Cold start: prevention of ice generation in the fuel cell stack that impedes the transportation of reactants and might cause permanently cell damages. Thus, its important to develop procedures to start the fuel cell system when temperatures are below zero and the freezing point.
- Proper water management: too high operating temperatures may lead to a dry out of the fuel cell whereas too low temperature may lead to water flooding. Therefore a fuel cell system requires a sophisticated water management

→ Please visit our YouTube channel and watch and listen to Dr. Johannes Schirmer from the German Aerospace Centre (DLR) explains the requirements for cooling and heating in a fuel cell electric vehicle, highlighting the differences compared to a conventional combustion car: https://www.youtube.com/watch?v=HXMXo3UiQDI

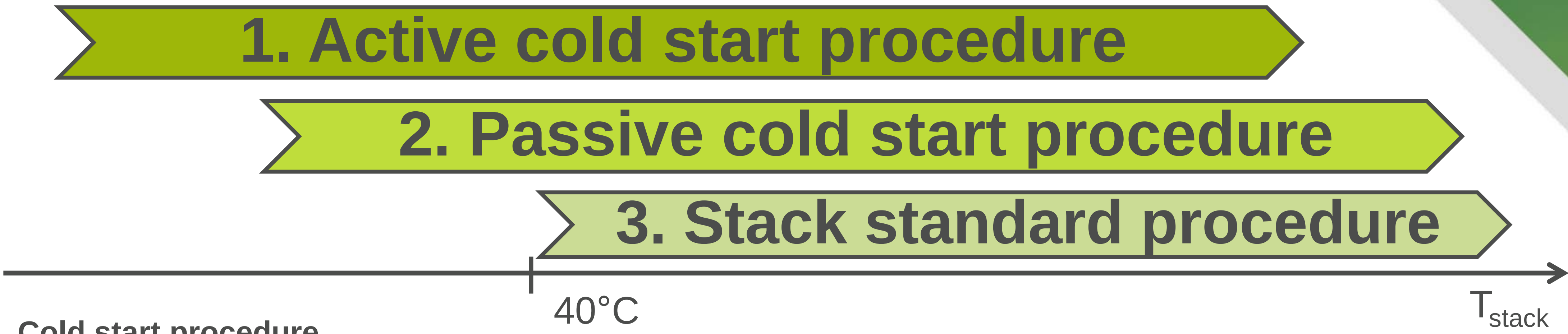
3. THERMAL MANAGEMENT SYSTEM COMPONENTS

- DC/DC converter
- Air compressor



- Low temperature cooling loop for the cooling of the cathode air compressor, the cathode heat exchanger and the DC/DC converter that connects the fuel cell stack to the high voltage bus
- Radiator + fan unit
- High temperature cooling loop for the thermal management of the FC stack. Waste heat is used for the heating of the vehicle cabin and the hydrogen feed
- Pump
- Small coolant loop with an electrical preheater used for cold start procedures

4. AN INNOVATIVE COLD START PROCEDURE



Cold start procedure

1. **Active cold start procedure:** closing of the small cooling loop connecting the input and the output of the fuel cell stack. The coolant will be pumped from the outlet to the inlet with the maximum flow rate and the heater will be switched on to heat the coolant
2. **Passive cold start procedure:** The compressor is started at high flow rate while the flow rate of the coolant is reduced at its minimum. The fuel cell will be run in potentiostatic mode, until it reaches nominal temperature and will then be commuted to galvanostatic mode. Once the stack reaches sufficient operation temperature, the coolant flow is smoothly shifted from the small loop to the main loop.
3. **Stack standard operation:** stack standard operation when stack temperature are above 40°C

Shutdown procedure

Cathode purge: consists of purging the cells with dry gases during an optimal purge time to remove water droplets.

5. SPECIFIC CHALLENGES RELATED TO THE DEVELOPMENT PROCESS

Development and test of an alternative cold start procedure with start-up capabilities of down to -40°C

- The German Aerospace Centre tests in INN-BALANCE, beside conventional freeze start, an alternative approach for an anti-freeze procedure based on the injection of an electrochemical active antifreeze fluid. The fluid prevents on the one side completely the formation of ice and secondly shall enable an optimized start-up of the system without heating or other devices. Implementing this integrated solution in fuel cells would improve efficiency and subzero handling of FC and reduce degradation during freeze start.

Selection of the most adapted components and calibration of the controllers

- After some pressure drops were observed, some components had to be improved to meet the specifications. The values of the constants of the thermal management controller also had to be reset to perform well at extreme conditions.

Compactness and compatibility with FC system

- The concept of the thermal management system should fulfil the vehicle specifications while minimizing the power consumption of the main actuator, the coolant pump

6. MAIN DEVELOPMENT STEPS

Steps taken during the development of the control system

1. Design and development of the thermal management concept and control scheme by DLR
2. Development of simulation models for the cooling circuits and of a low temperature circuit concept that minimizes the system components and improves the system efficiency by Brose
3. Development of a dedicated test bed by DLR to test a new concept for freeze conditioning based on the use of methanol as anti-freeze liquid for flooding of the anode and cathode compartments
4. Manufactured-oriented redesign of the thermal module by Brose to improve packaging and increase the overall efficiency
5. Testing and evaluation of the thermal system by DLR prior to its implementation in a FC system and further validation in laboratory environment by PowerCell