European Commission

HARMONISED TESTING HARDWARE FOR PEM SINGLE FUEL CELL

JRC ZERO∇CELL

Guidelines for manufacturing and operation

Tomasz Bednarek

ID-FAST Final Workshop - EFC21

16th December 2021

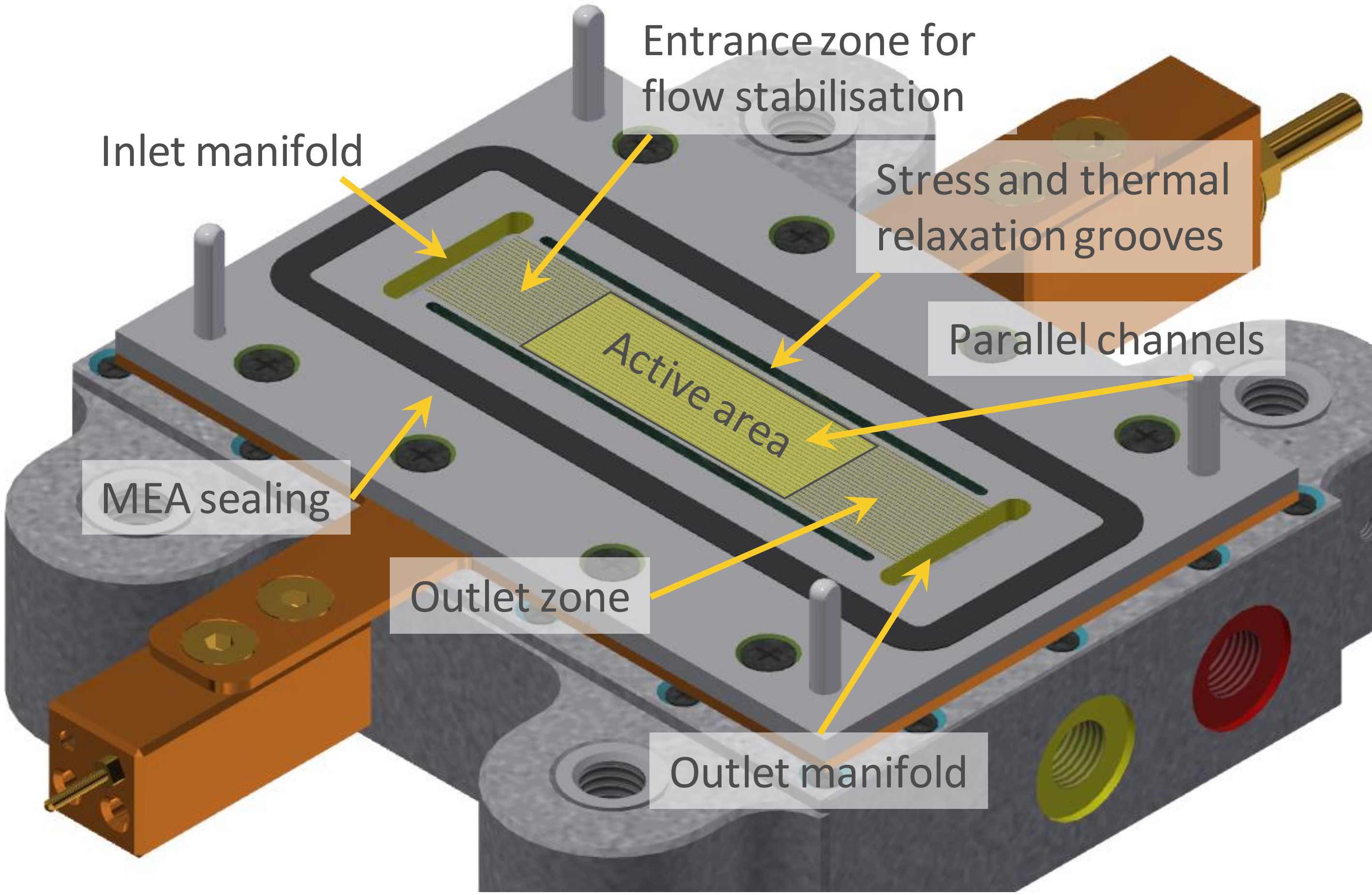
Joint Research Centre

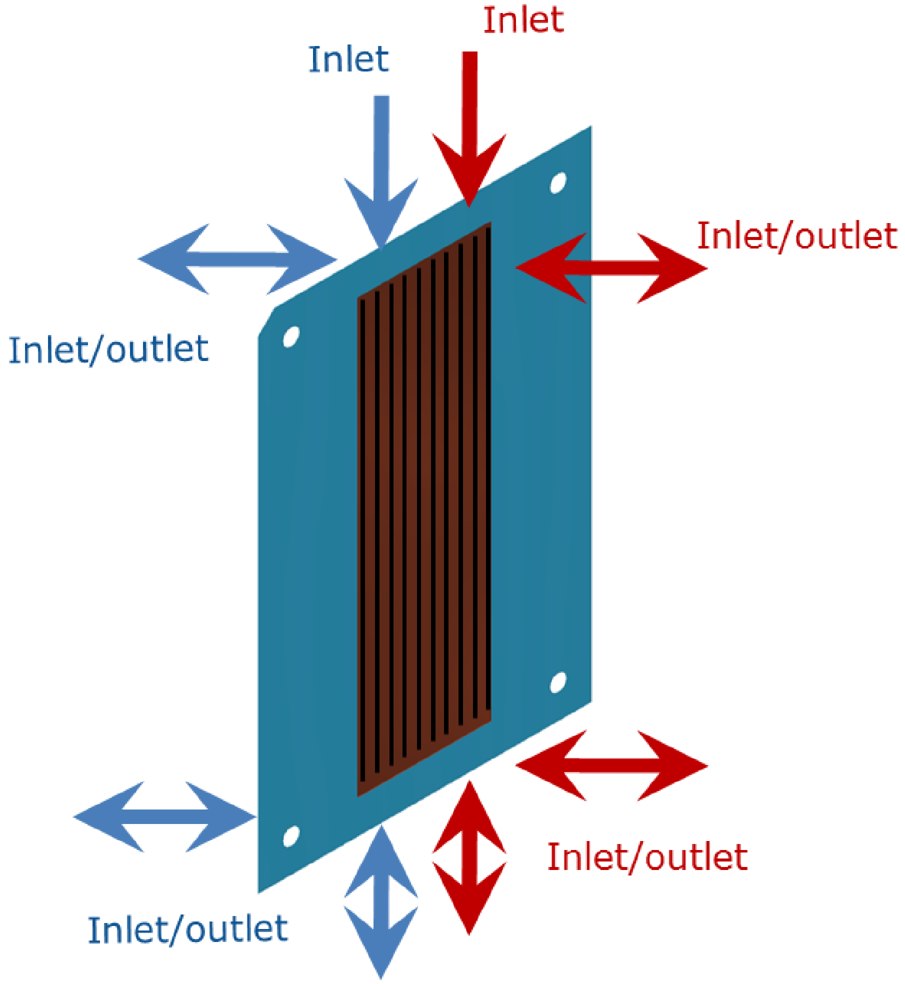
Design criteria and features of JRC ZERO∇CELL

Active area 10 cm^2 (20 x 50 mm in length)
Flow field with parallel channels
Counter-flow and co-flow operation mode options
Pneumatic MEA compression
Independent liquid-cooling circuits for anode and cathode compartments
Monitoring of operating conditions at the inlet and outlet gas manifolds
Temperature distribution monitoring at anode and cathode by thermocouples located inside the bi-polar plates
Maximum reactant gas pressure drop of 10kPa @4.0A cm^{-2}
Temperature variation across the active area of $\pm 1.0^{O}C$ @4.0 Acm^{-2}

European Commission

Flow-field features





Gasketing system is able to accommodate a wide range of MEA thicknesses

European Commission

Temperature monitoring at active area

Position of thermocouples (yellow)
5 anode and 5 cathode (10 in total):

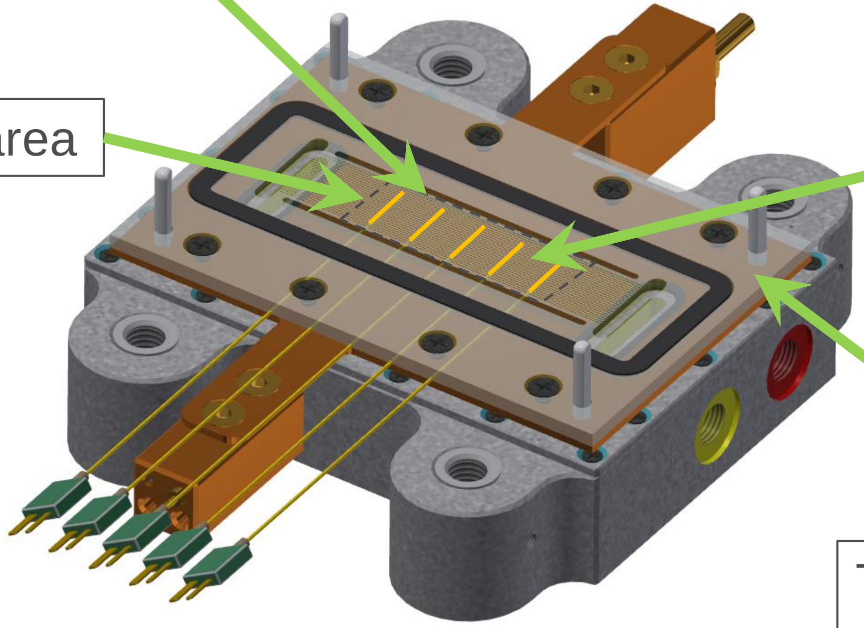
- **Beginning of active area**
- **25% of active area length**
- **50% of active area length**
- **75% of active area length**
- **End of active area**

Position of thermocouples inside graphite bi-polar plates, 3mm from MEA.

Sliding thermocouples to cover the whole active area width

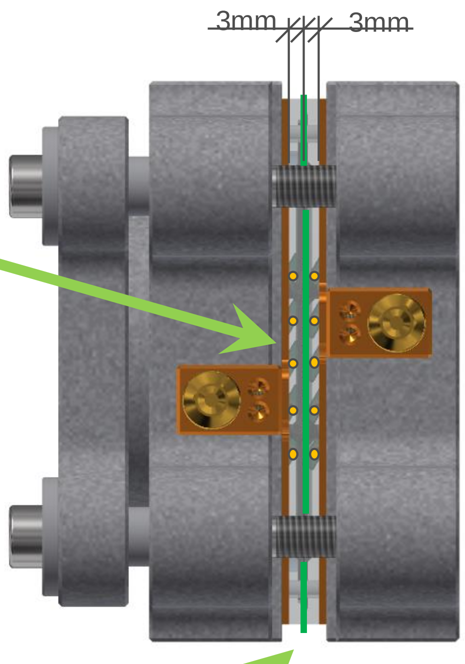
Active area

Location of thermocouple tips



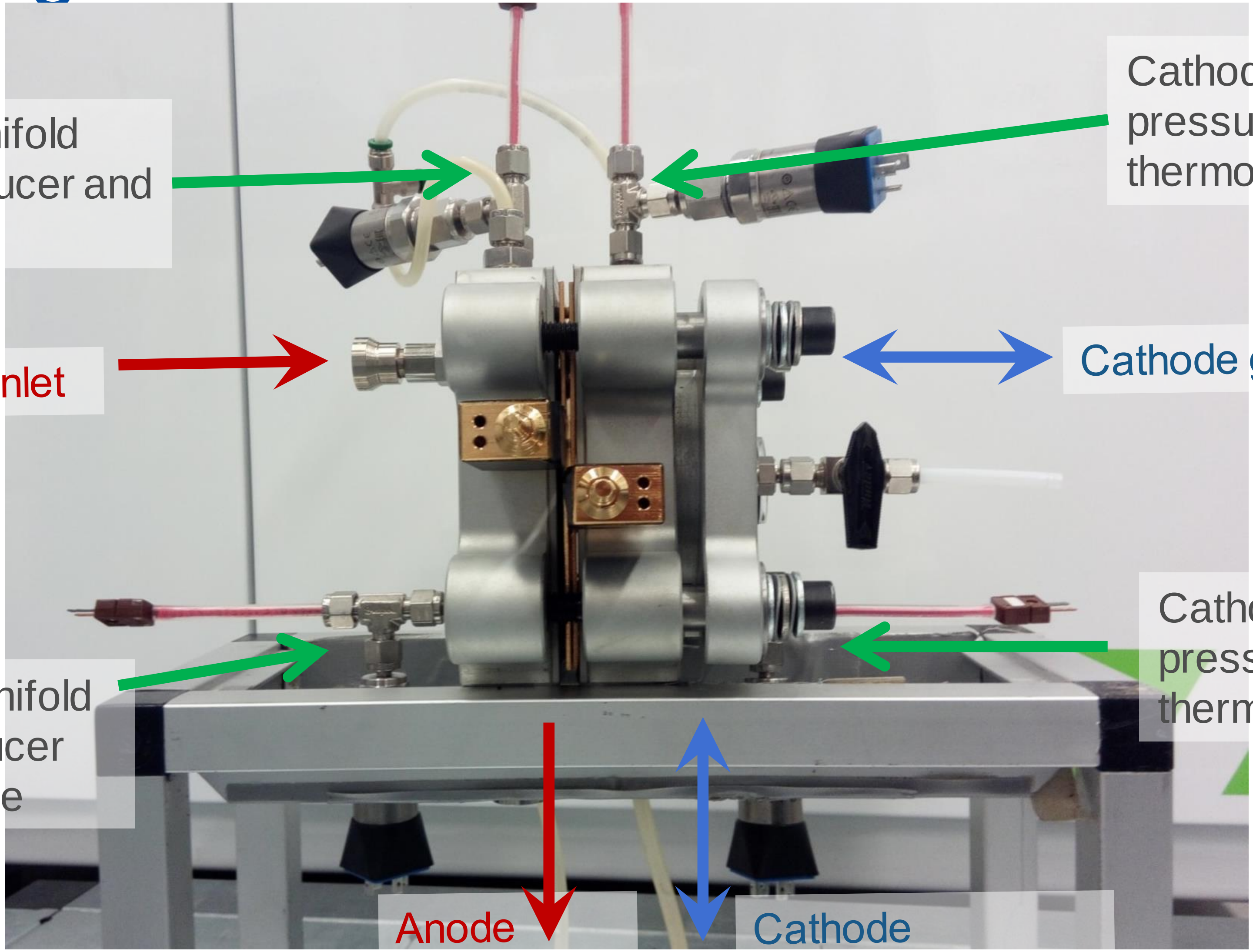
Transparent bi-polar plate view

Side view

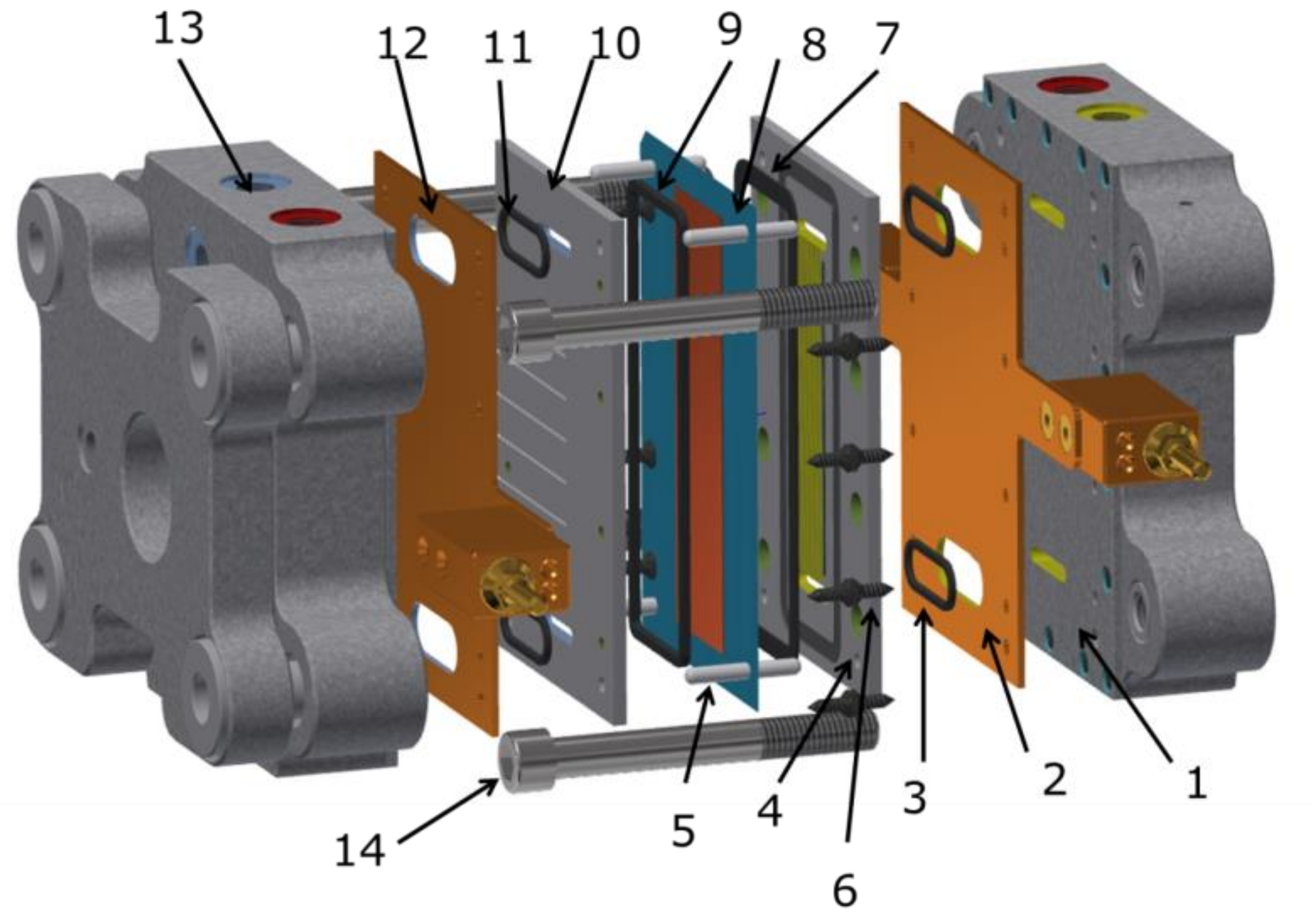


MEA

Monitoring of operating conditions inside gas manifolds



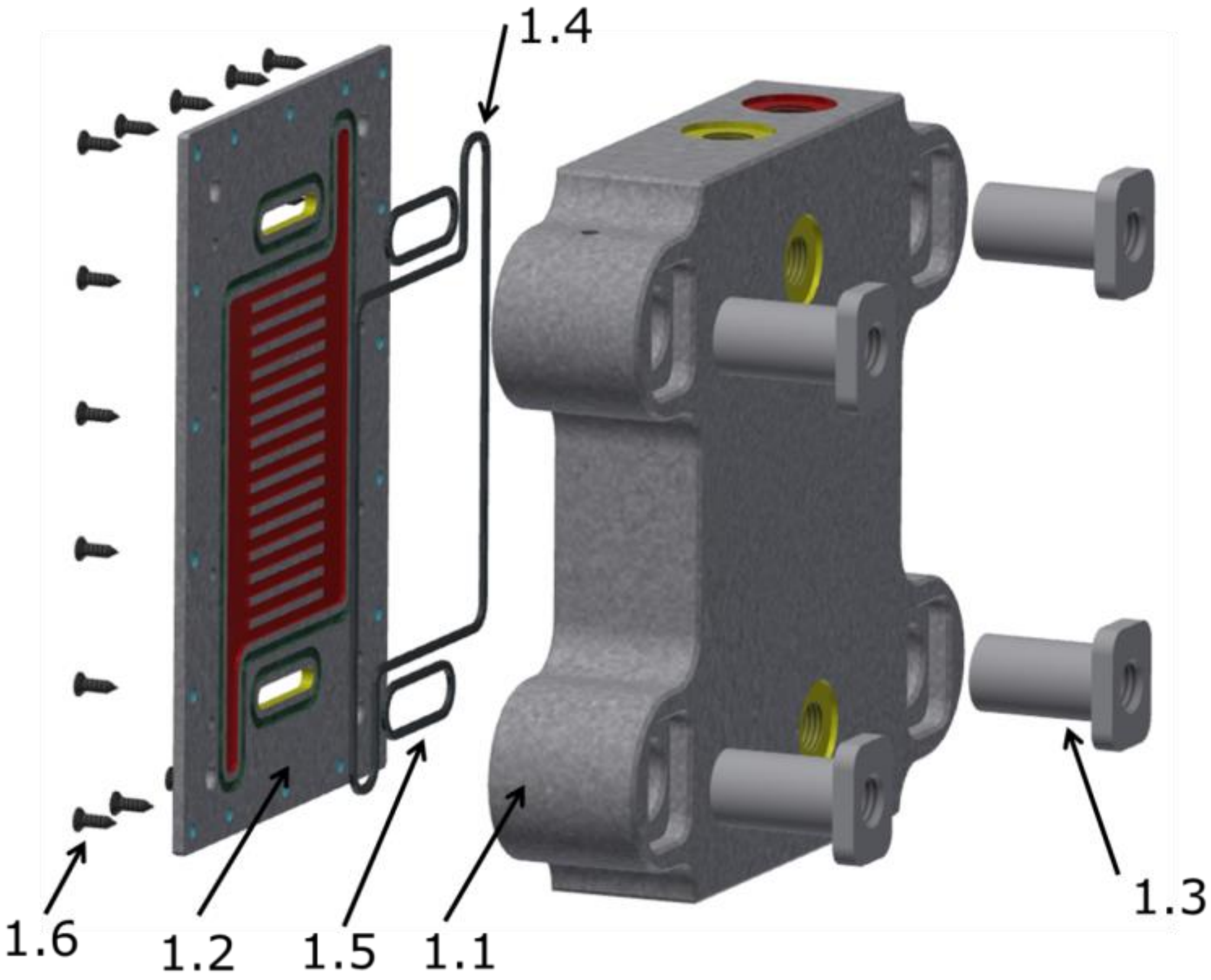
JRC ZERO∇CELL assembly



1. Anode end-plate unit
2. Anode current collector, copper, gold plated
3. Gas sealing, 2 pcs, o-ring 2.62x26.64 70 NBR
4. Anode bi-polar plate, graphite grade FC-GR347B
5. Positioning pin, 4 pcs, nylon
6. Fixing screws, 16 pcs, M4x12 flat head, nylon
7. Anode MEA sealing, 1pcs, custom made, silicon
8. MEA
9. Cathode MEA sealing – 1 pcs, custom made (silicon)
10. Cathode bi-polar plate, graphite grade FC-GR347B
11. Gas sealing, 2 pcs, o-ring 2.62x26.64 70 NBR
12. Cathode current collector, copper gold coated
13. Cathode end-plate unit
14. Clamping bolt, M12x120
15. Fittings (not shown):
    - 15.1. Gas inlet/outlet fittings, G1/4", 8 pcs.
    - 15.2. Coolant inlet/outlet fittings, G1/4", 4 pcs.
    - 15.3. Compressed air port, G1/8", valve,1pcs.
16. Pressure gauge for compression chamber, 0-30 bar, G1/8" (not shown)

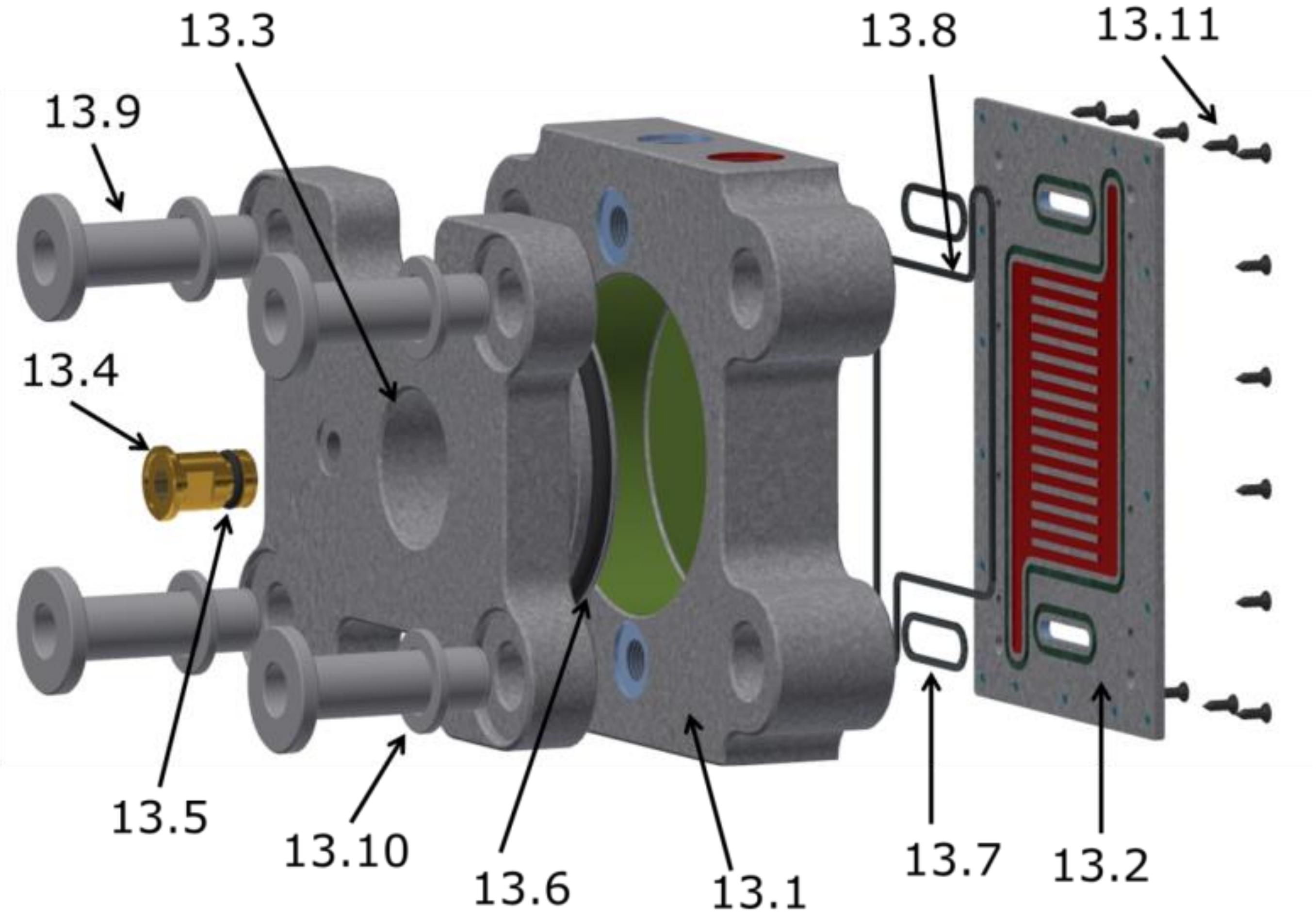
European Commission

Anode end-plate unit assembly



1.1. Anode end-plate, aluminium alloy grade AW 2024, anodised
1.2. Anode end plate lid, aluminium alloy grade AW 2024, anodised
1.3. Nut,4 pcs, brass or galvanised steel
1.4. Coolant circuit sealing, 1 pcs, o-ring 1.78x126.72 70NBR
1.5. Gas sealing, 2 pcs, o-ring 1.78x26.7 70NBR
1.6. Fixing screws, 18 pcs, M3x10,flat head, stainless steel

Cathode end-plate unit assembly



13.1. Cathode end-plate, aluminium alloy grade AW 2024, anodised

13.2. Cathode end-plate lid, aluminium alloy grade AW 2024, anodised

13.3. Cathode pressurising plate, aluminium alloy grade AW 2024, anodised

13.4. Pressure gauge fitting for compression chamber – custom made, brass, circlip 16mm

13.5. Sealing of pressure gauge fitting, 1 pcs, o-ring 2.62x10.77 70NBR, back-up ring 11.2x15.5x1.2 PTFE

13.6. Sealing of compression chamber, 1 pcs, x-ring 5.33x81.92 70 NBR, back-up ring 82.2x91x2.0 PTFE, use vacuum sealing grease

13.7. Gas sealing, 2 pcs, o-ring 1.78x26.7 70NBR

13.8. Coolant circuit sealing, 1 pcs, o-ring 1.78x126.72 70NBR

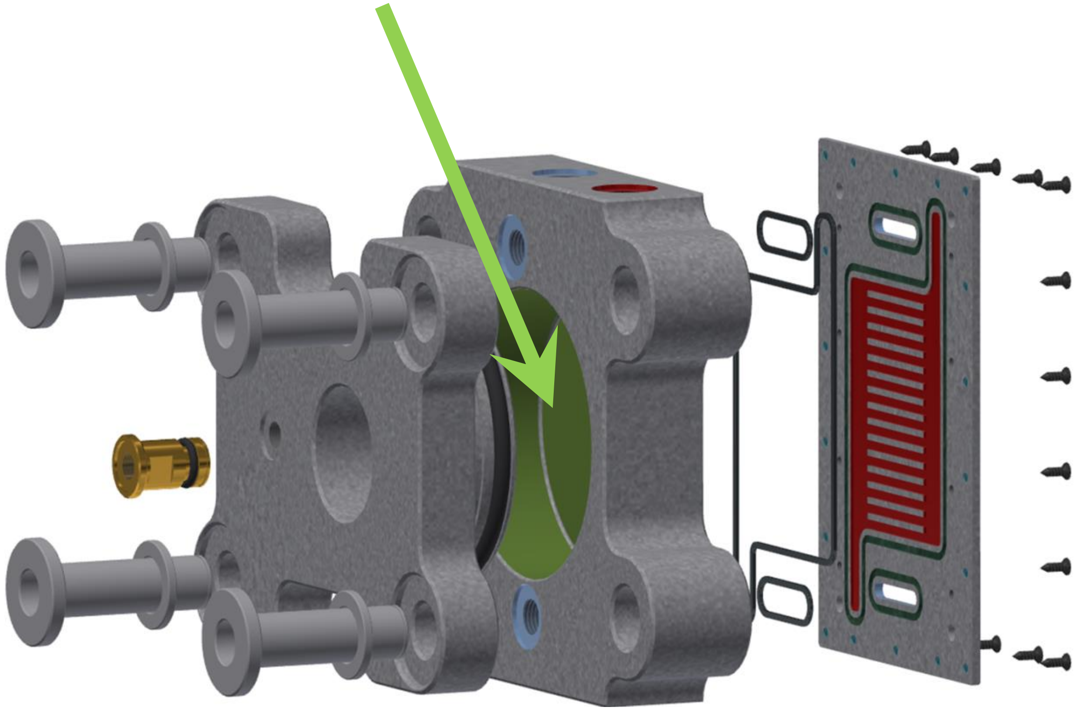
13.9. Bolt sleeve, 4 pcs, brass of stainless steel

13.10. Fixing washer, 4 pcs, brass or stainless steel; 4pcs, circlip 17mm

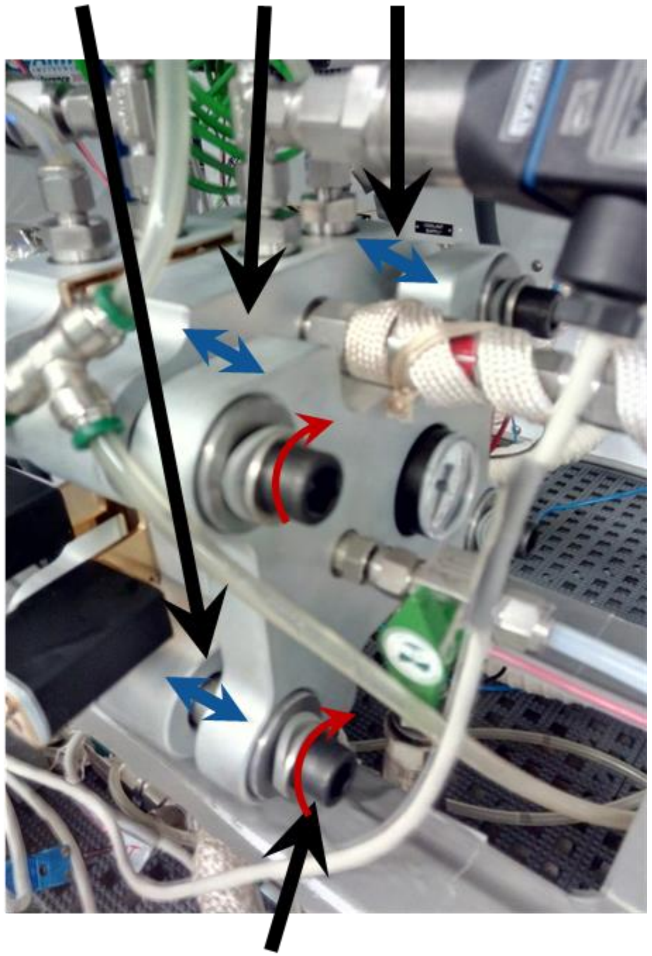
13.11. Fixing screws, 18 pcs, M3x10, stainless steel

Pneumatic compression system

Compression chamber



Parallelism accuracy ~5mm



Clamping bolt

Used materials

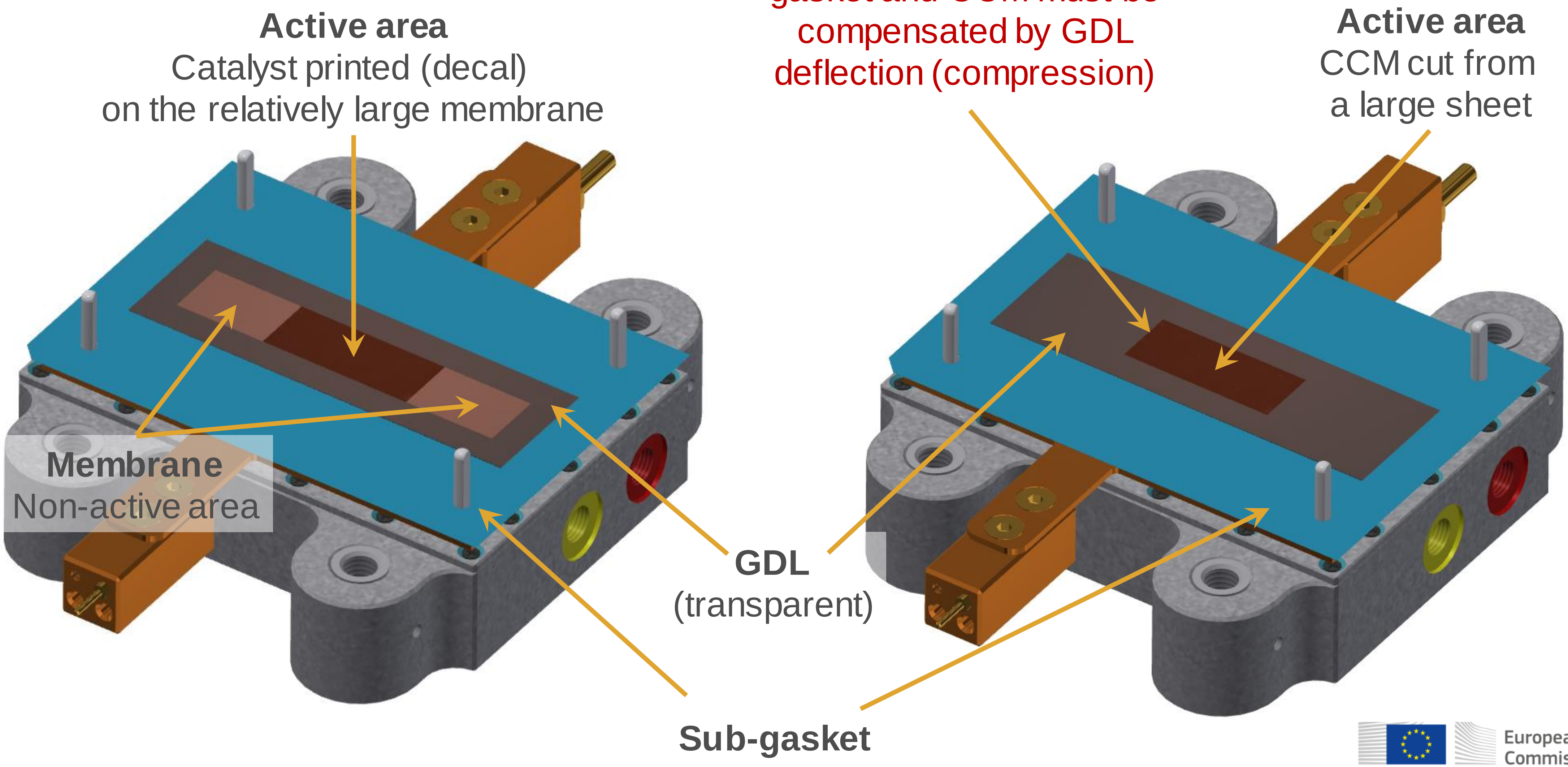
- **End-plate** bodies are made of aluminium alloy grade AW 2024 (ISO AlCu4Mg1), often used in aircraft industry due to its lightweight and mechanical strength.
- **Bi-polar plates** are made of graphite grade FC-GR347B. This material is gas-tight (compound) combining good electric and thermal conductivity.
- **Current collectors** are made of copper, while electric terminals are of brass. Gold coating (>0.5μm) should include nickel or silver underlay for better preparation of the coated surface.

Graphite Grade	Fuel Cell Grade (FC-GR347B)
Bulk Density	1.99 g cm^{-3}
Temperature Range	Max: 170 °C
Strength	65 MPa
Particle Size	0.0254 mm
Electrical Resistivity	0.0012 ohm m
Porosity	0%

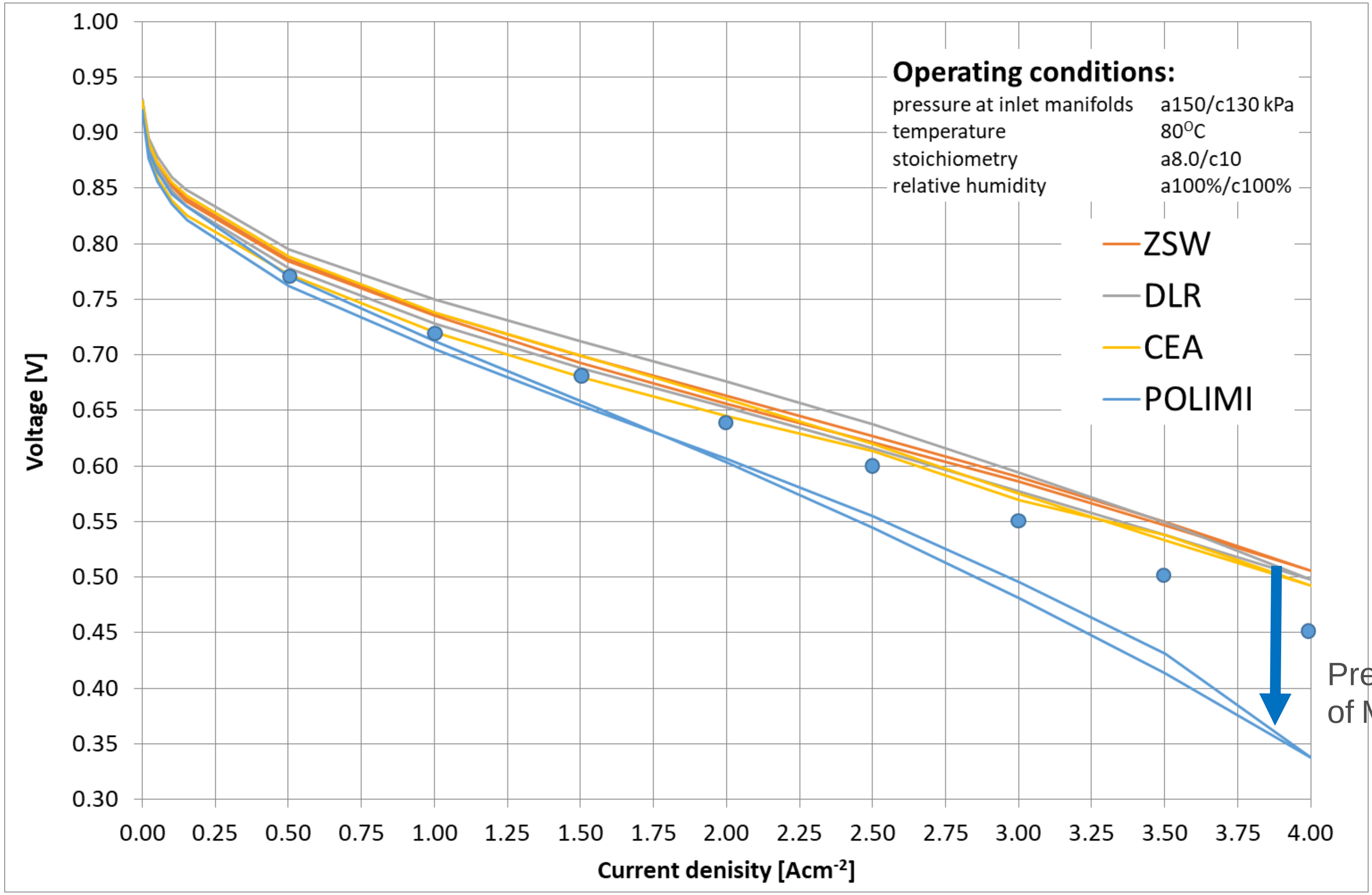
Used materials

- All sealings, except MEA sealing are taken from the stock (o-rings, NBR or viton, hardness ~70 Shore).
- MEA gaskets are custom made (i.e. laser cut) to accommodate various MEA thicknesses. The base material is flat sealing sheet (NBR or silicon), hardness 35÷40 Shore.
- Gas and coolant fittings G1/4''.
- Compressed air for pneumatic compression system G1/8''

MEA preparation



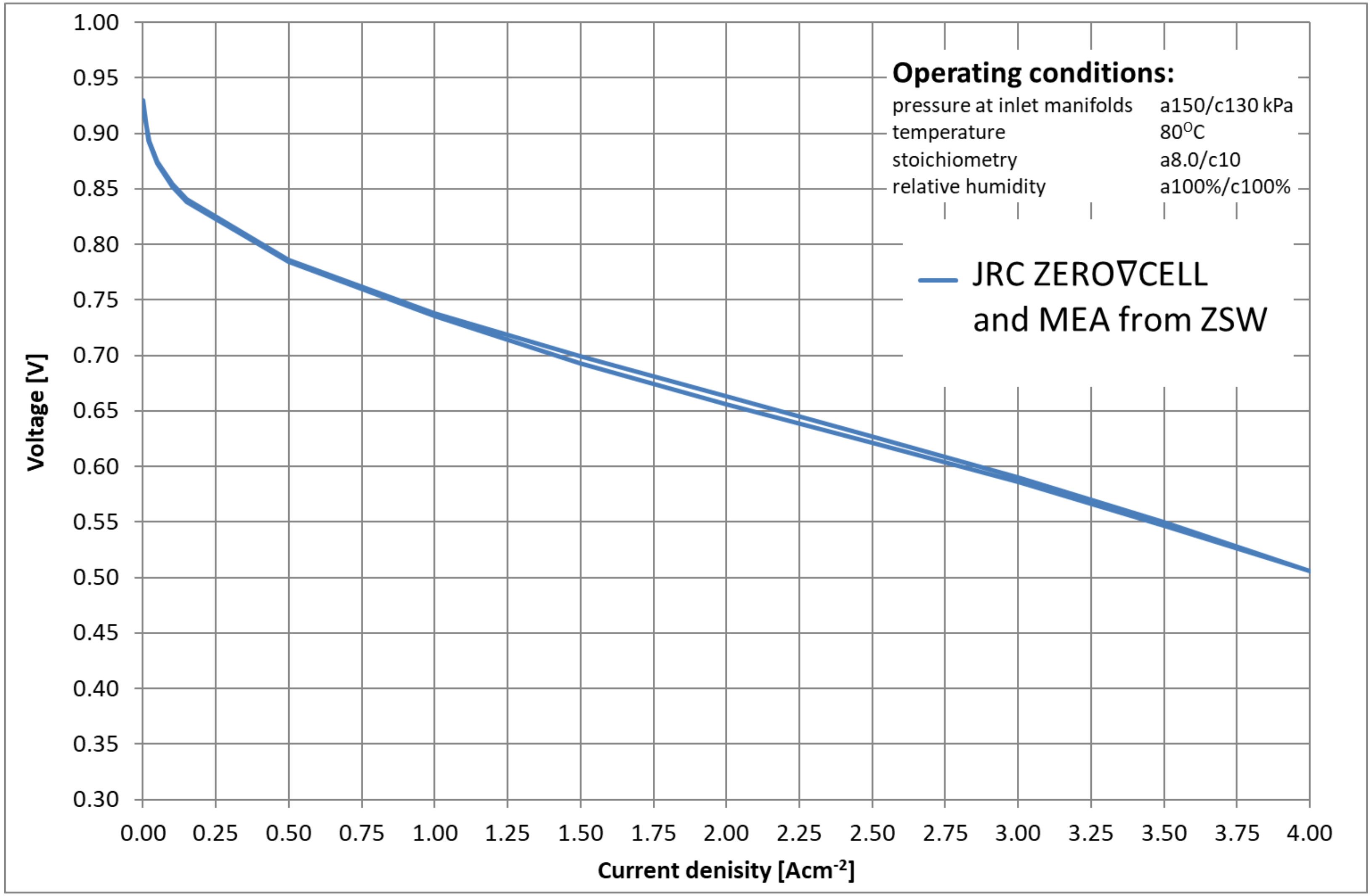
Experiments for IDFAST



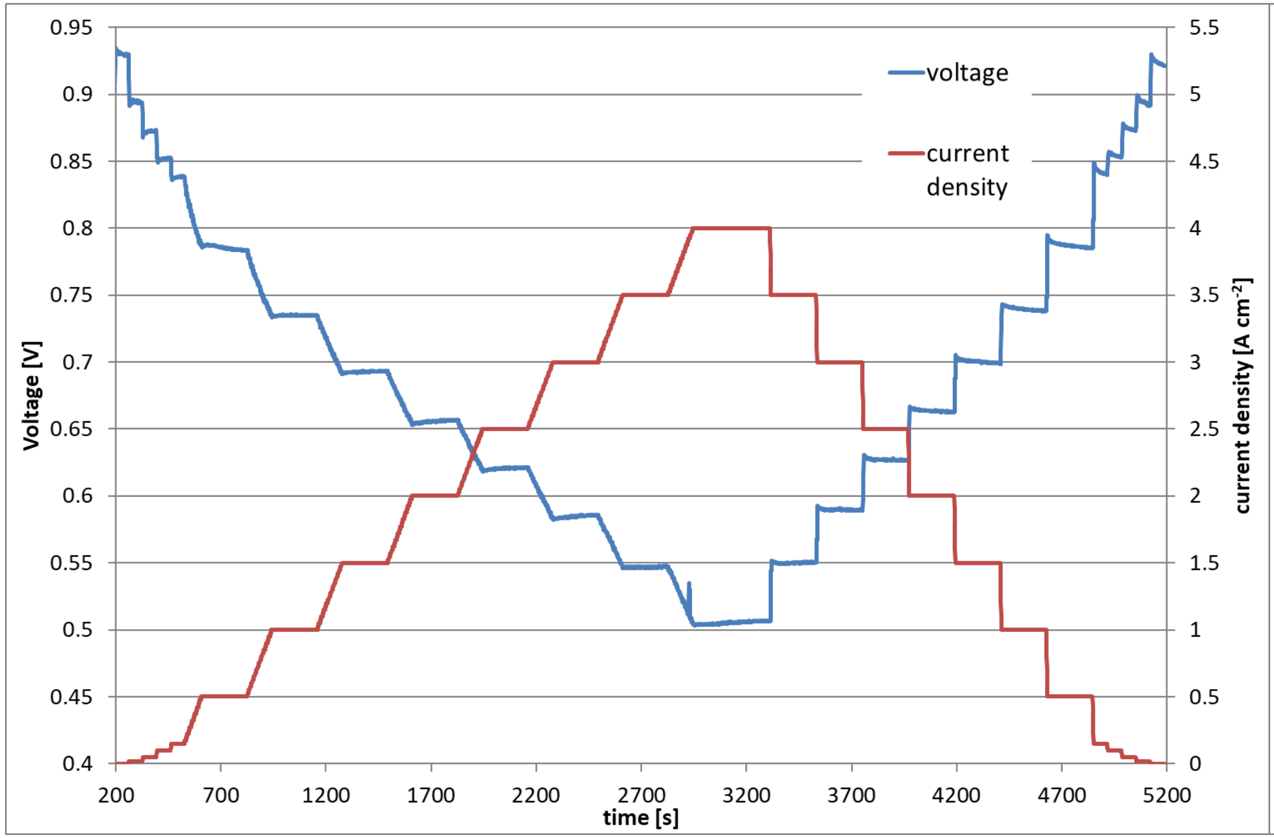
Premature degradation of MEA from POLIMI

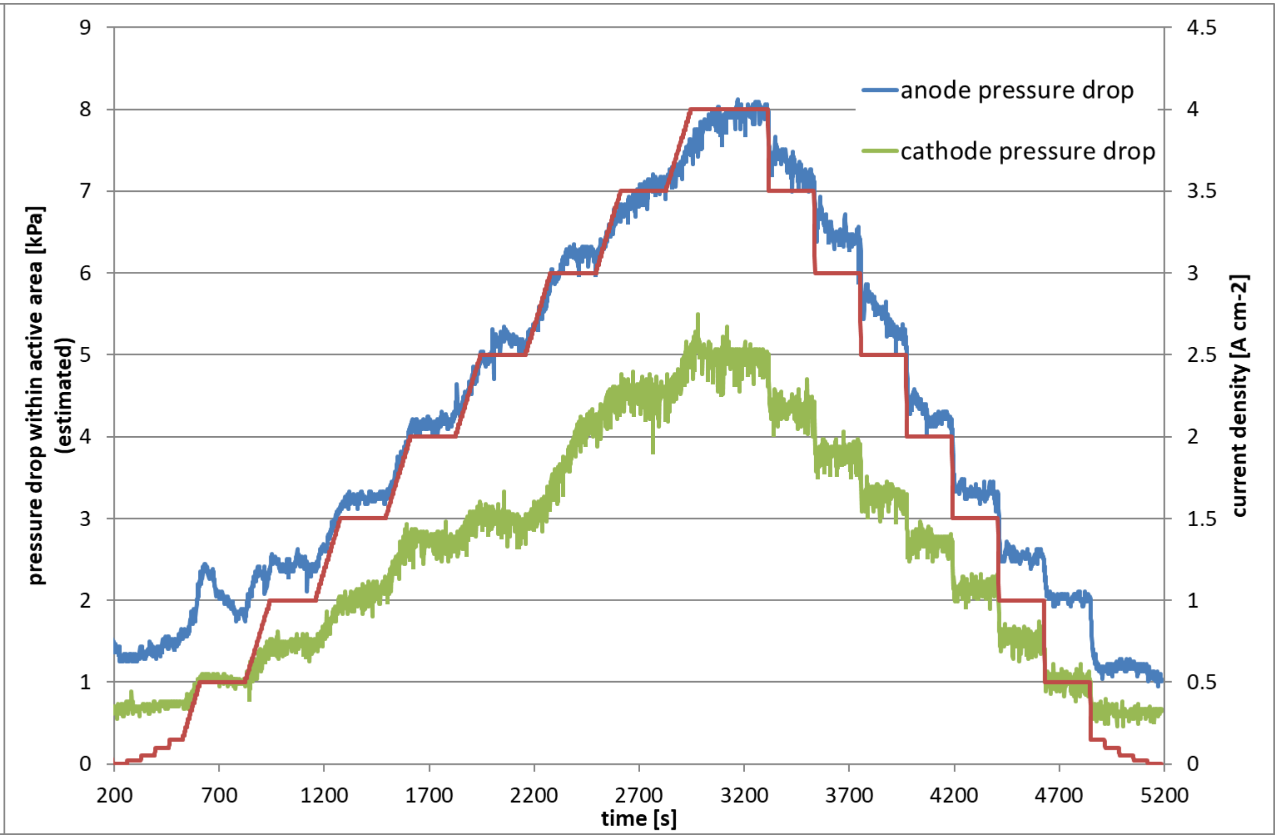
European Commission

Experiments for IDFAST

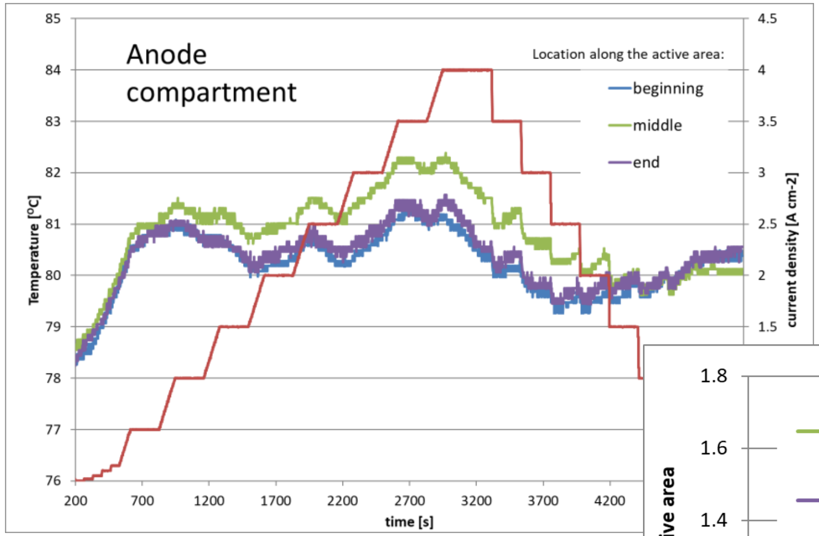


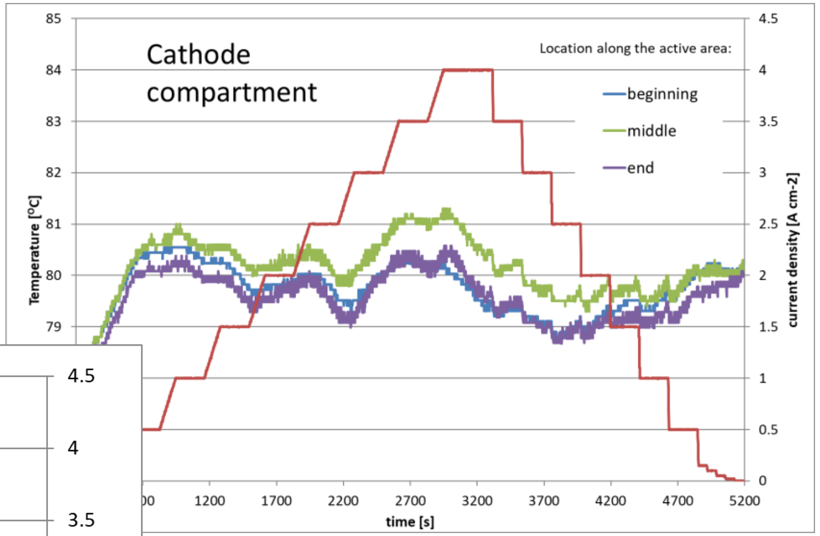
Experiments for IDFAST

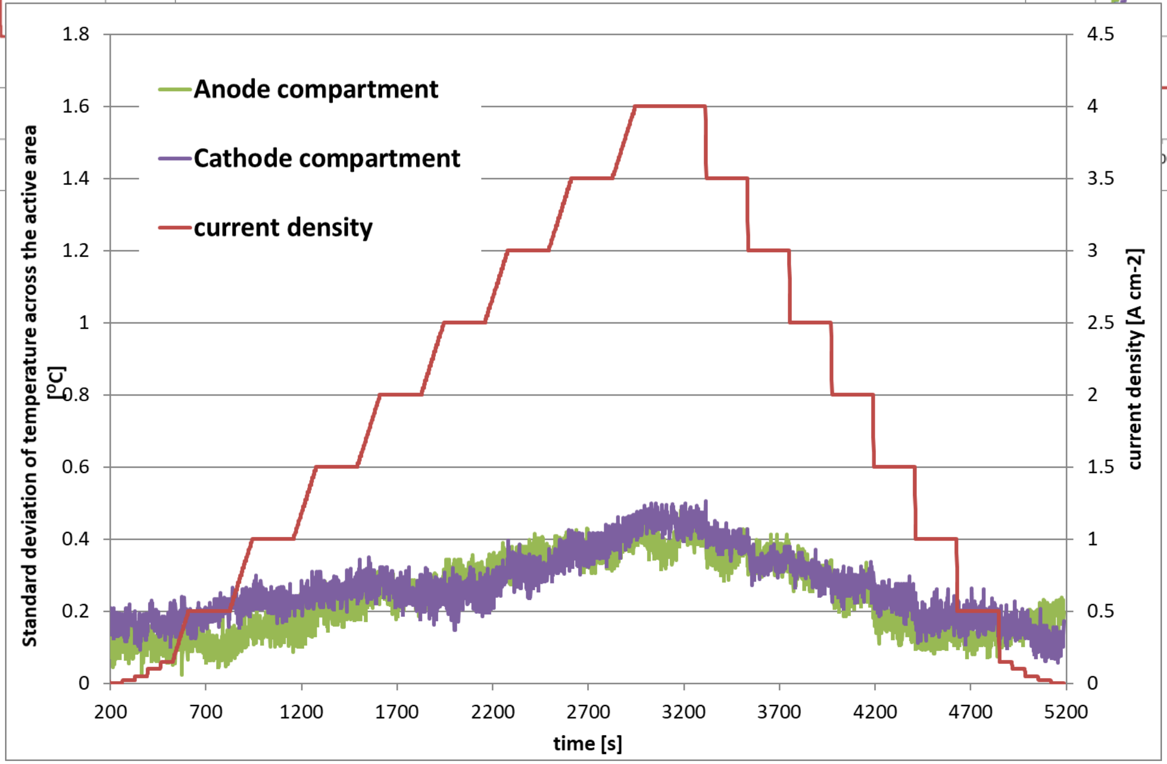




Experiments for IDFAST

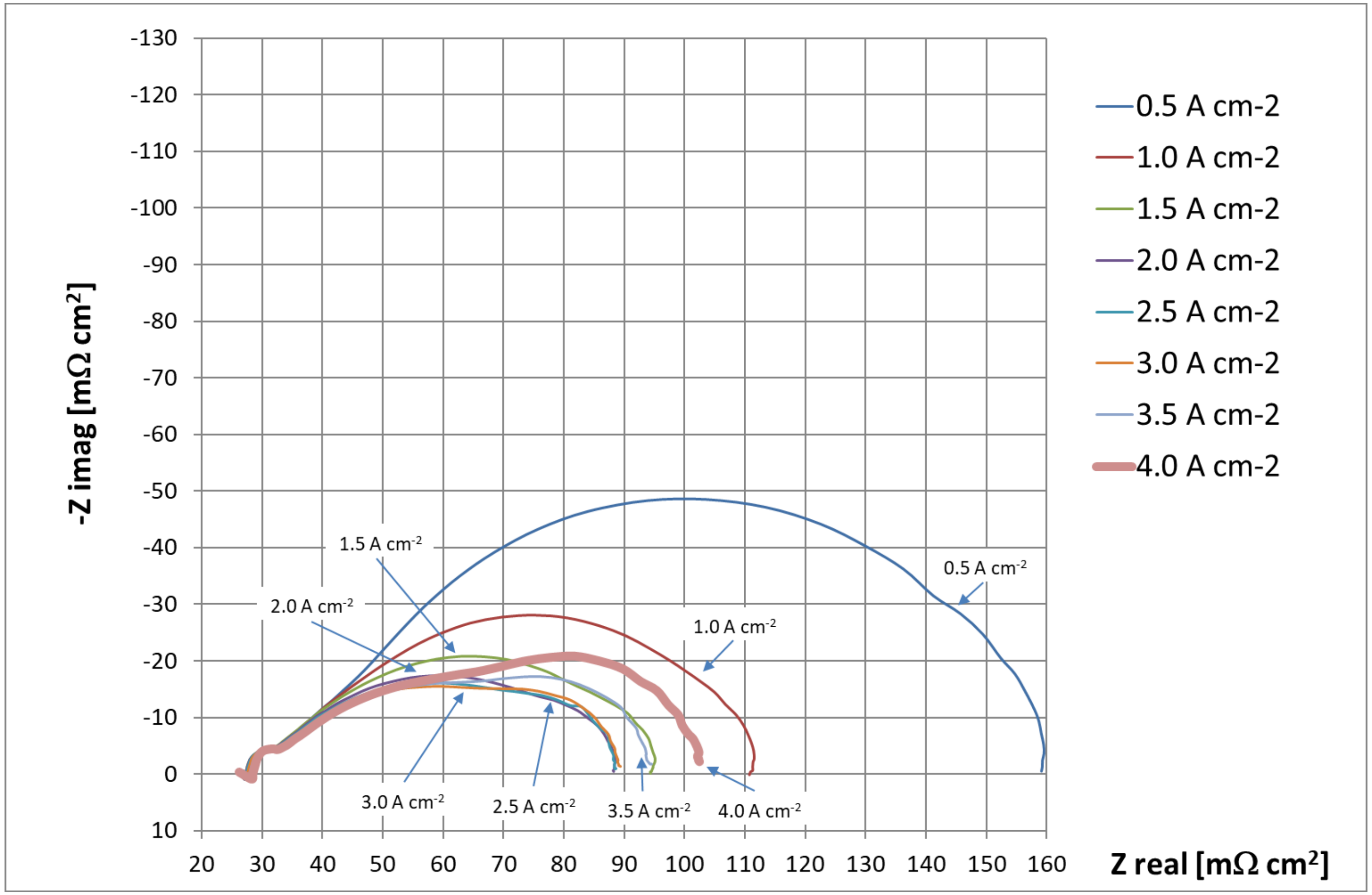






Experiments for IDFAST

EIS tests
100 kHz -> 1Hz



Final remarks

- Although there were some early childhood problems, it seems all issues are tackled.
- Some parts of the JRC ZERO∇CELL are rather complex in manufacturing. Quality control is crucial here.
- Manufacturing tolerances are sometimes very tight, however they are necessary to satisfy design criteria of the JRC ZERO∇CELL.
- Selection of materials is very important, especially for bi-polar plates (for good electrical and thermal conductivity) and end-plates (for mechanical strength).
- Preparing of MEAs to be tested could be difficult at the beginning. Bear in mind that thickness step between active and non-active area must be compensated by GDL compression.
- Due to relatively high operating stoichiometry rates and current densities, humidity control of inlet gases has a knock-on effect on obtained results.
- The design documentation of the JRC ZERO∇CELL is publicly available at doi:0.17632/c7bffdv7yb.1 under CERN Open-Hardware license.

Experimental validation

Contents lists available at ScienceDirect
Journal of Power Sources
journal homepage: www.elsevier.com/locate/jpowsour

Assessment of the electrochemical characteristics of a Polymer Electrolyte Membrane in a *reference* single fuel cell testing hardware

Tomasz Bednarek *, Georgios Tsotridis
European Commission, Joint Research Centre (JRC), Directorate C Energy Transport and Climate, the Netherlands

Data in Brief 31 (2020) 105945
Contents lists available at ScienceDirect
Data in Brief
journal homepage: www.elsevier.com/locate/dib

Data Article

Comparison of experimental data obtained using the *reference* and the single-serpentine proton exchange membrane single fuel cell testing hardware

Tomasz Bednarek*, Georgios Tsotridis
European Commission, Joint Research Centre (JRC), Directorate C Energy Transport and Climate, The Netherlands

[1] T. Bednarek, G. Tsotridis, *Assessment of the electrochemical characteristic of a polymer electrolyte membrane in a “reference” single fuel cell testing hardware*, JPS, (2020), doi: 10.1016/j.jpowsour.2020.228319.

[2] T. Bednarek, G. Tsotridis, *Comparison of experimental data obtained using the reference and the single-serpentine proton exchange membrane single fuel cell testing hardware*, DiB 31 (August 2020) 105945, doi: 10.1016/j.dib.2020.105945.

[3] T. Bednarek, G. Tsotridis, Development of reference hardware for harmonised testing of PEM single cell fuel cells, EUR 30592 EN, Publications Office of the European Union, Luxembourg, 2021, ISBN 978-92-76-30231-5, doi:10.2760/83818.

[4] The JRC ZERO∇CELL design documentation, Mendeley Data (2021), V1, doi: 10.17632/c7bffdv7yb.1

European Commission

Thank you

Keep in touch

Tomasz.Bednarek@ec.europa.eu

+31 22 456 54 47

European Commission