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The Impact of Off-spec Conditions on the Performance of a PEM fuel Cell

R.C. Makkus

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The Impact of Off-spec Conditions on the Performance of a PEM Fuel Cell

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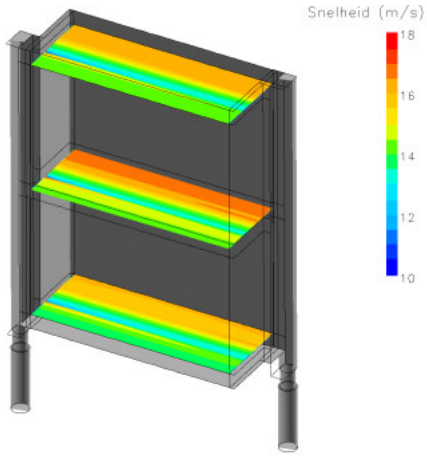
- Conclusions

Introduction

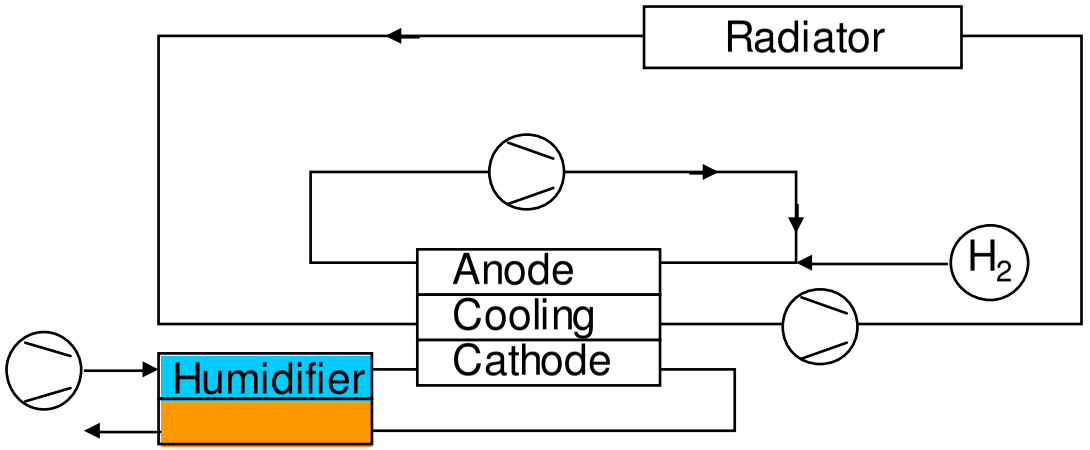
- Performance of cell and stack depend on:
  - Process conditions like T, p, λ, RH
    - dictated by system
  - Reactant distribution inside the stack and cell



- Tool available for measuring current profile

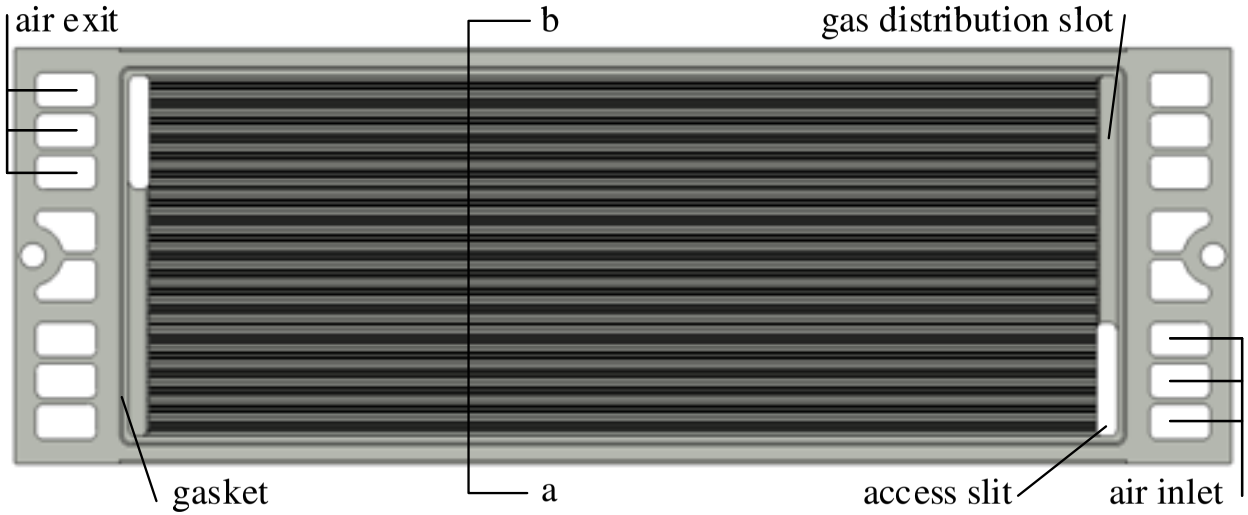
Introduction

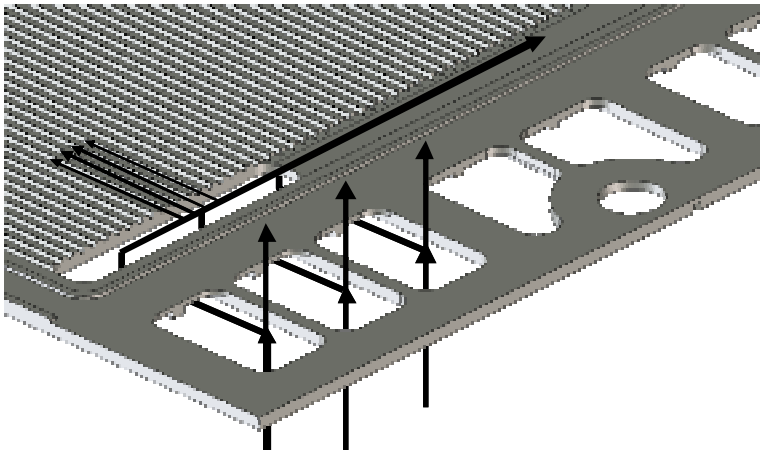
- System



- Stack/system failure modes
  - Malfunctioning of of the gas humidifying hardware ⇒ low RH of cathode gas
  - Heat loss in H_2 recirculation ⇒ low RH of anode gas
  - Malfunctioning blower or compressor, a gas leakage, or a (partial) blockage of the gas supply by water droplets, resulting in (local) fuel or oxidant starvation
  - Gas accumulation in the cooling circuit causing a hotspot

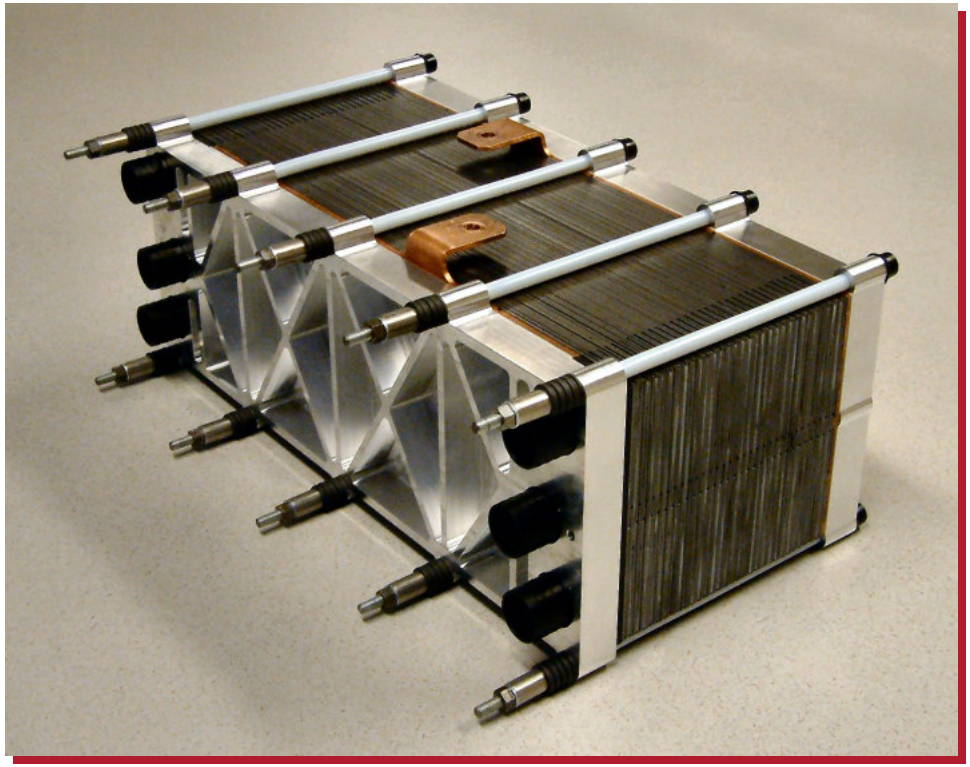
Experimental





Experimental

- Cell design used in 5 kW stack
  - Aplied in a scooter and a small electric vehicle

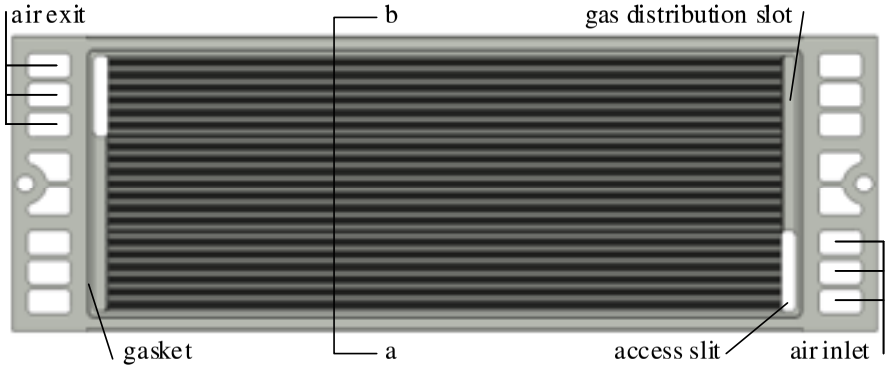


Experimental

- Influence cathode and anode humidification temperature
- Temperature excursion
- Stoichiometry

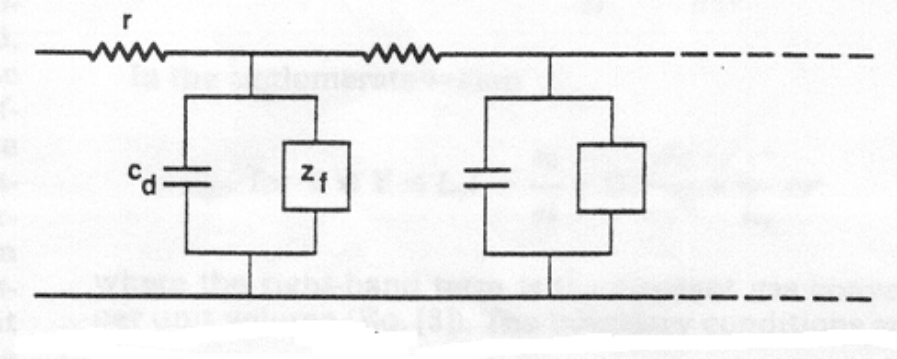
- Standard conditions
  - Overall current density: 800 mA/cm^2
  - λ_{H_2} : 2
  - T_{hum}: 65 °C
  - λ_{Air} : 2
  - T_{hum}: 65 °C
  - T_{cell} : 65 – 70 °C

- Electrochemical characterisation
  - EIS ⇒ R_Ω, R_{pol}, R_p
  - CV ⇒ ECSA, C_{dl}
  - CA ⇒ H_2 cross-over



Experimental

- Analysis EIS
  - Catalyst layer can be treated as transmission line

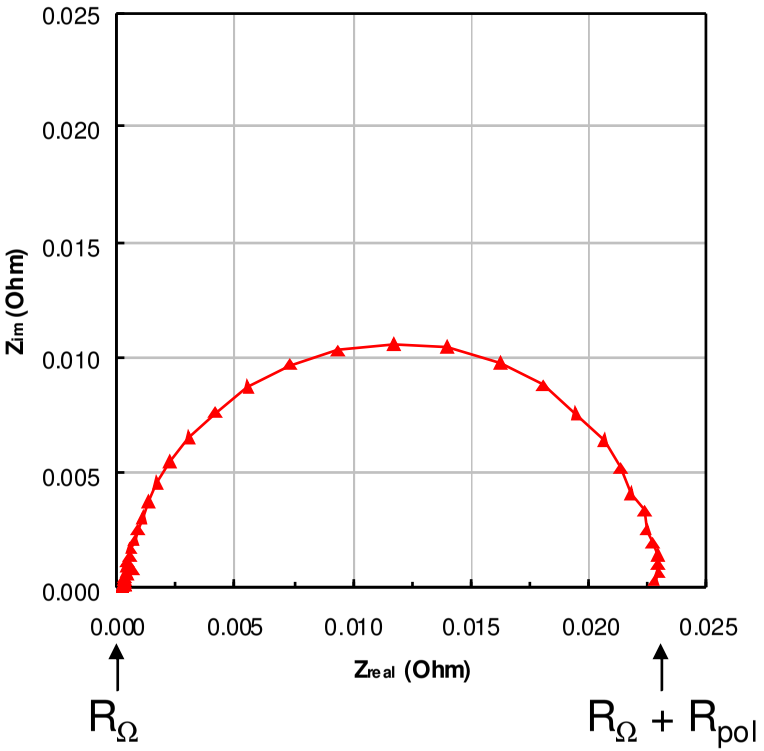


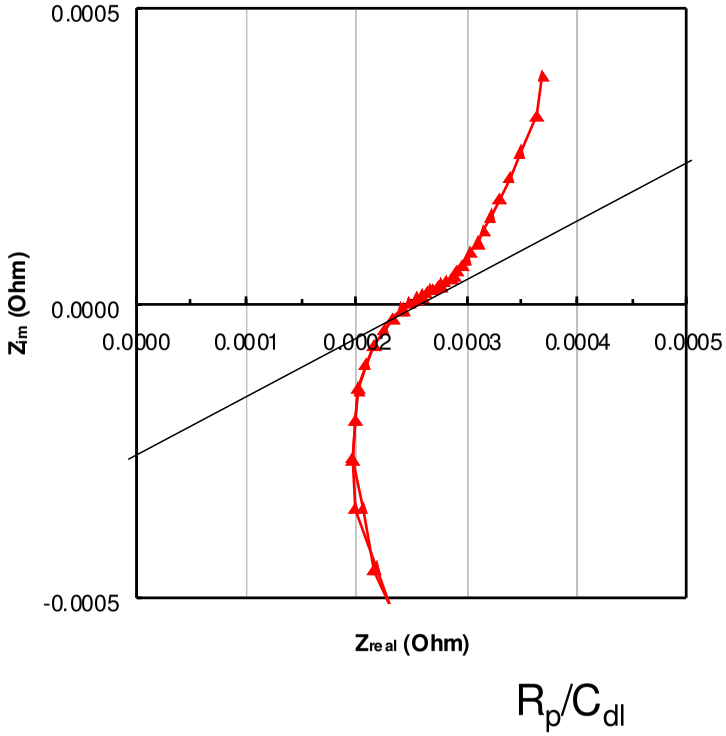
  - High frequency limit

$$Z(\omega) = R_{\Omega} + \sqrt{\frac{R_p}{C_{dl}}}\omega^{-1/2}\,\frac{\sqrt{2}}{2}(1-i)$$

Experimental

- Analysis EIS

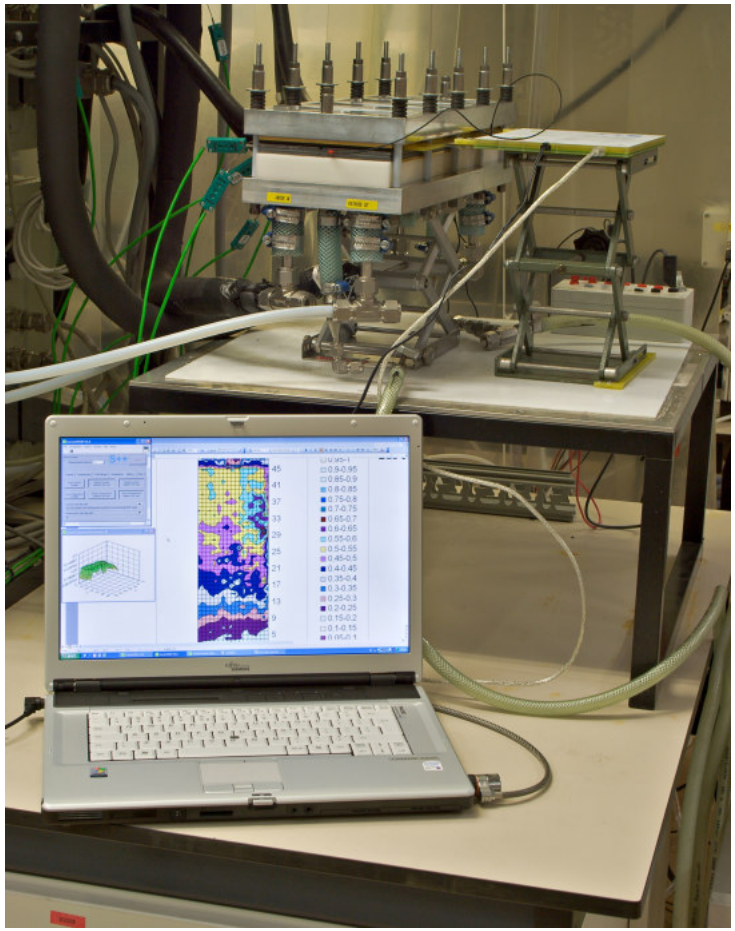




Experimental

Current profiling (S++):

- Coil measures current in a square of 0.5cm^2
- 864 (18x48) spots @ 400 cm^2
- Can be used with single cell or stack

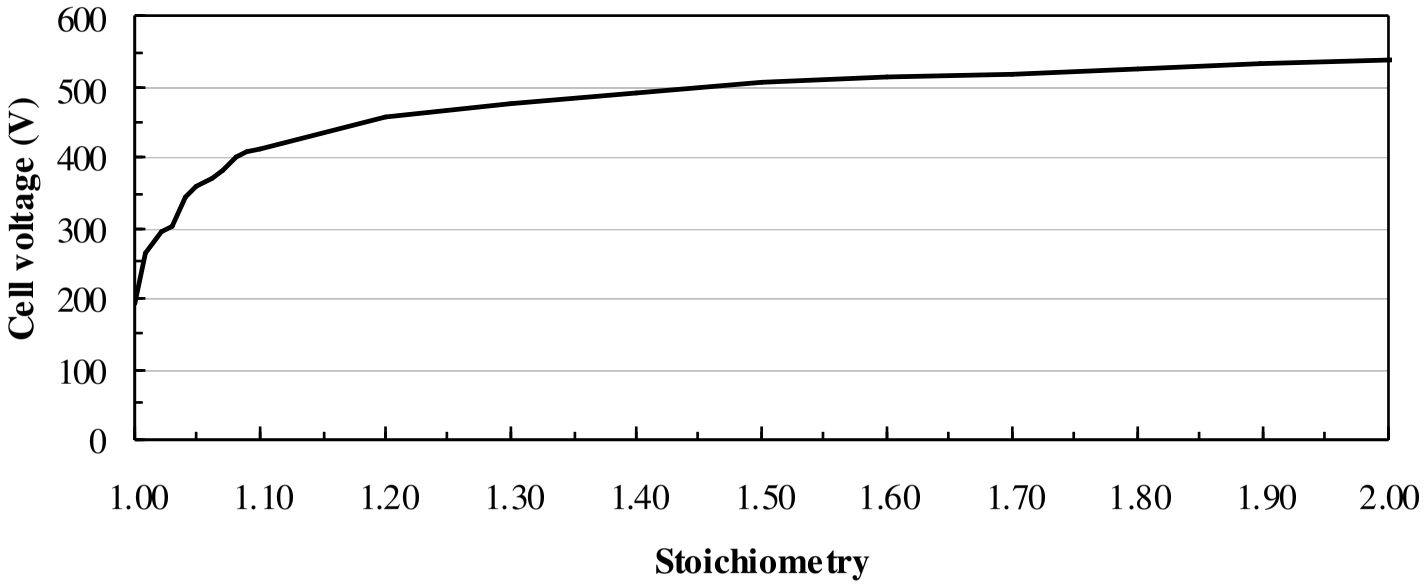


Results

- **Effect stoichiometry**

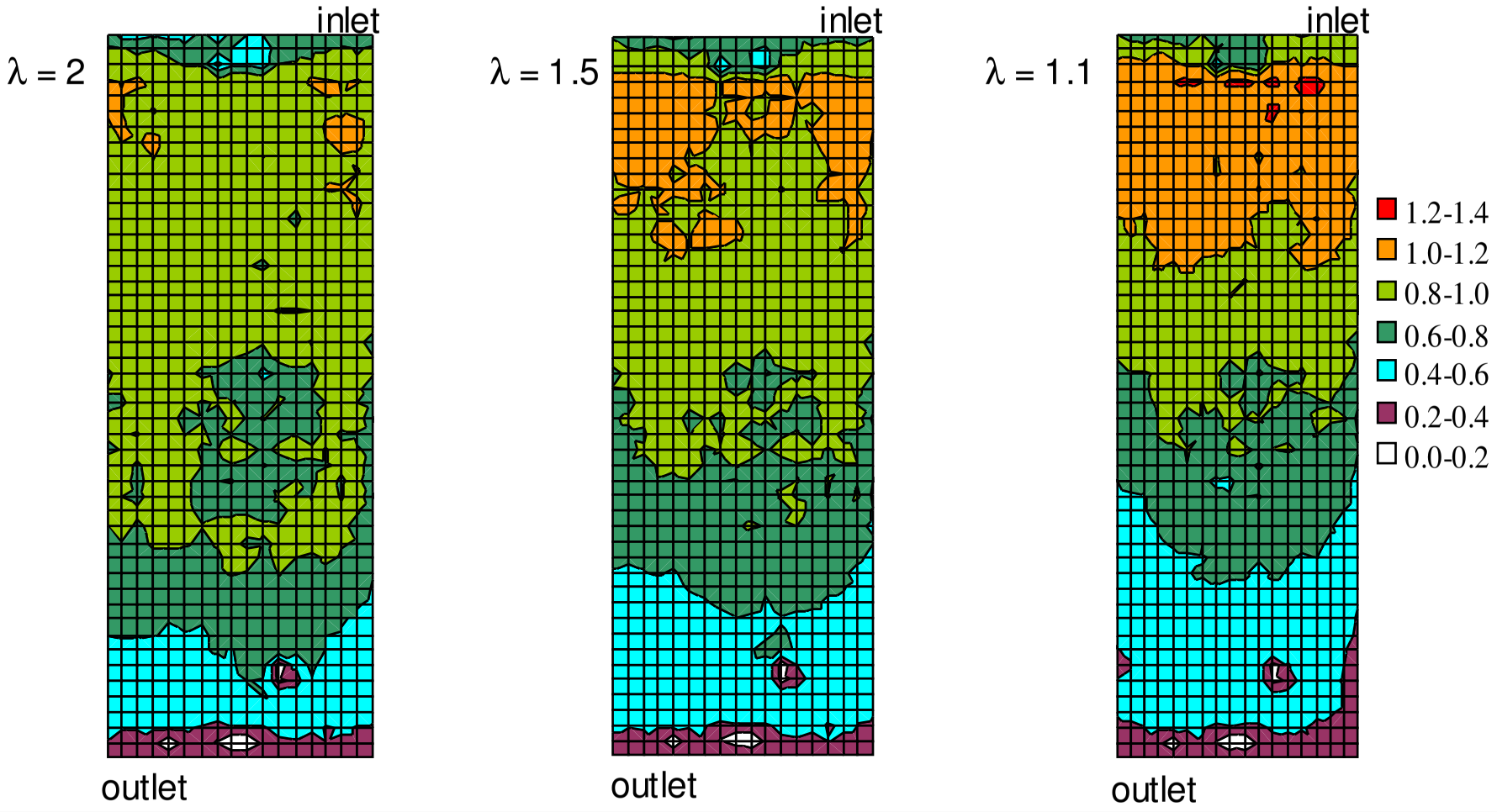
Results

- Effect stoichiometry



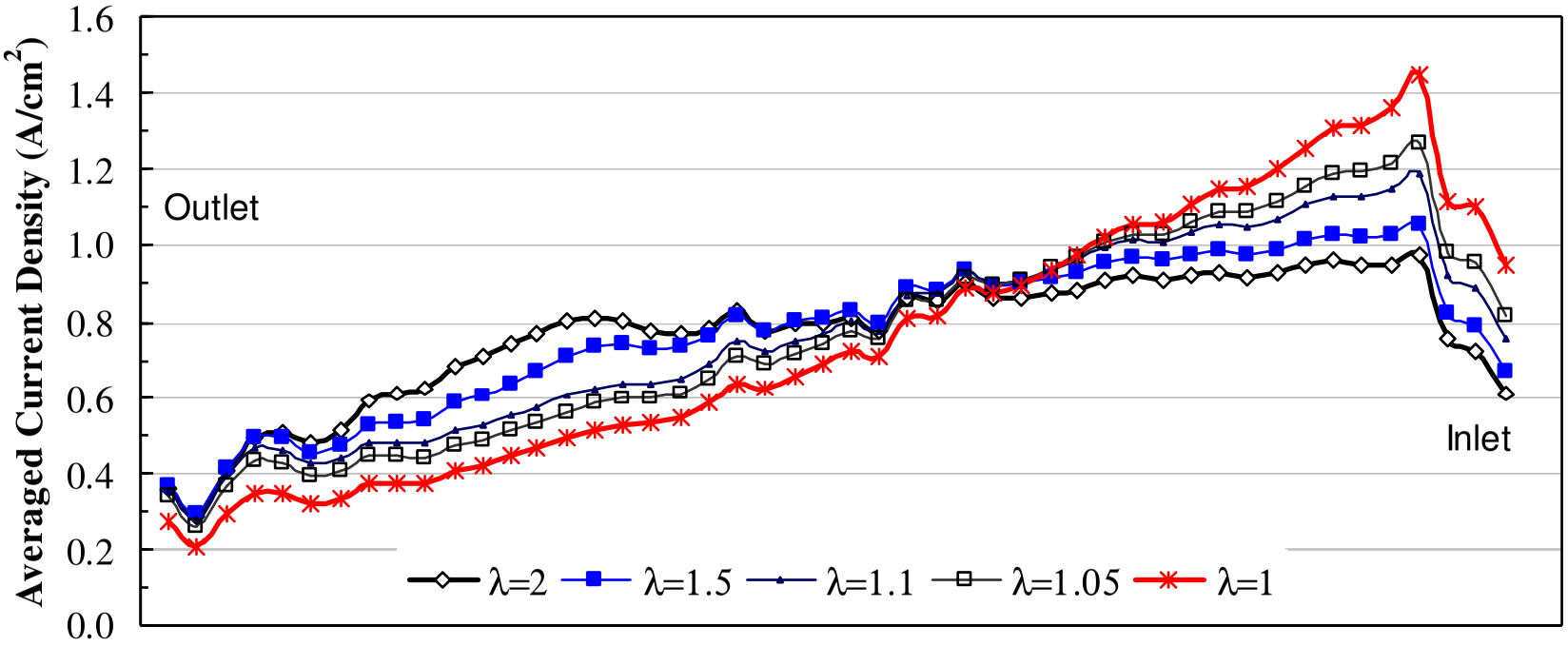
Results, current density distribution

- Effect stoichiometry



Results, current density distribution

- Effect stoichiometry

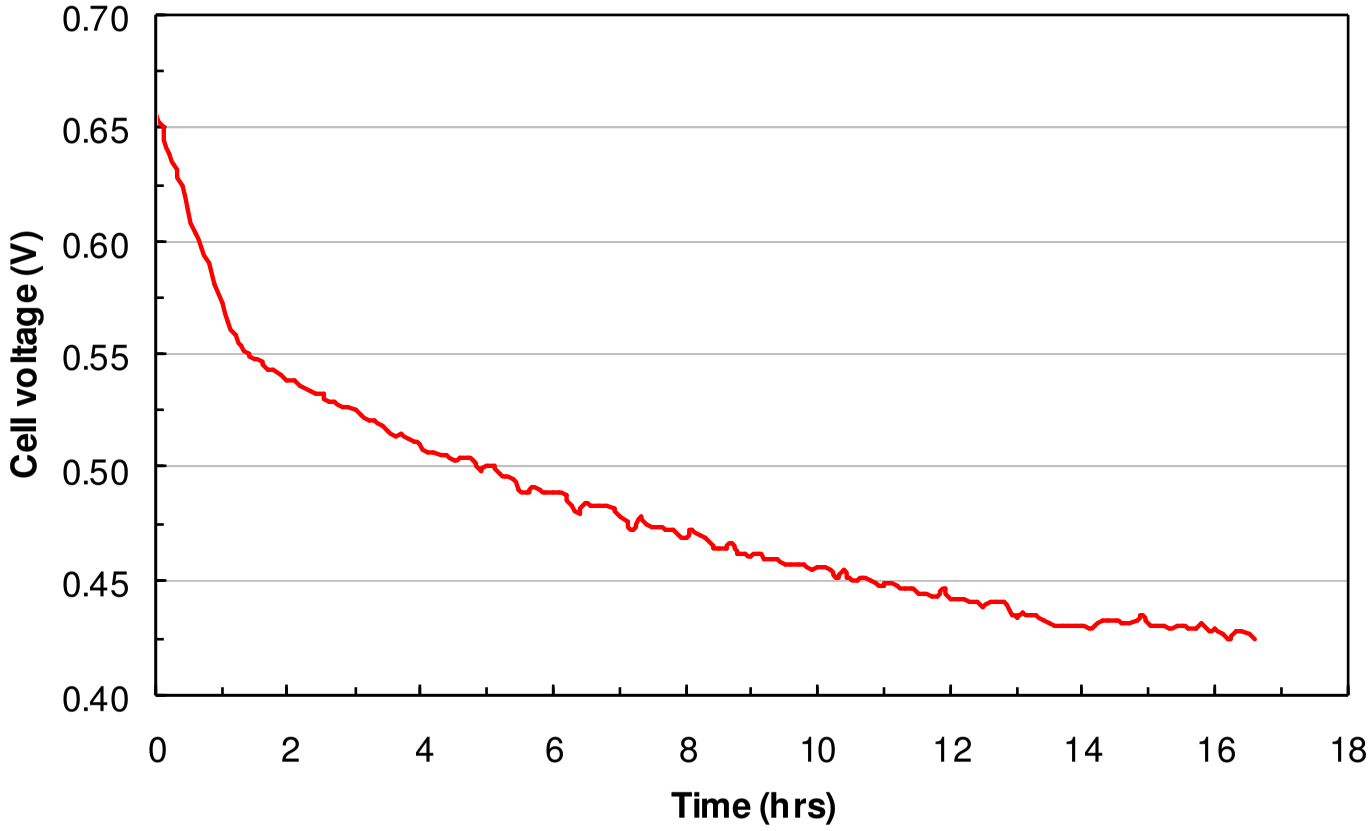


Results

- **Effect humidification**

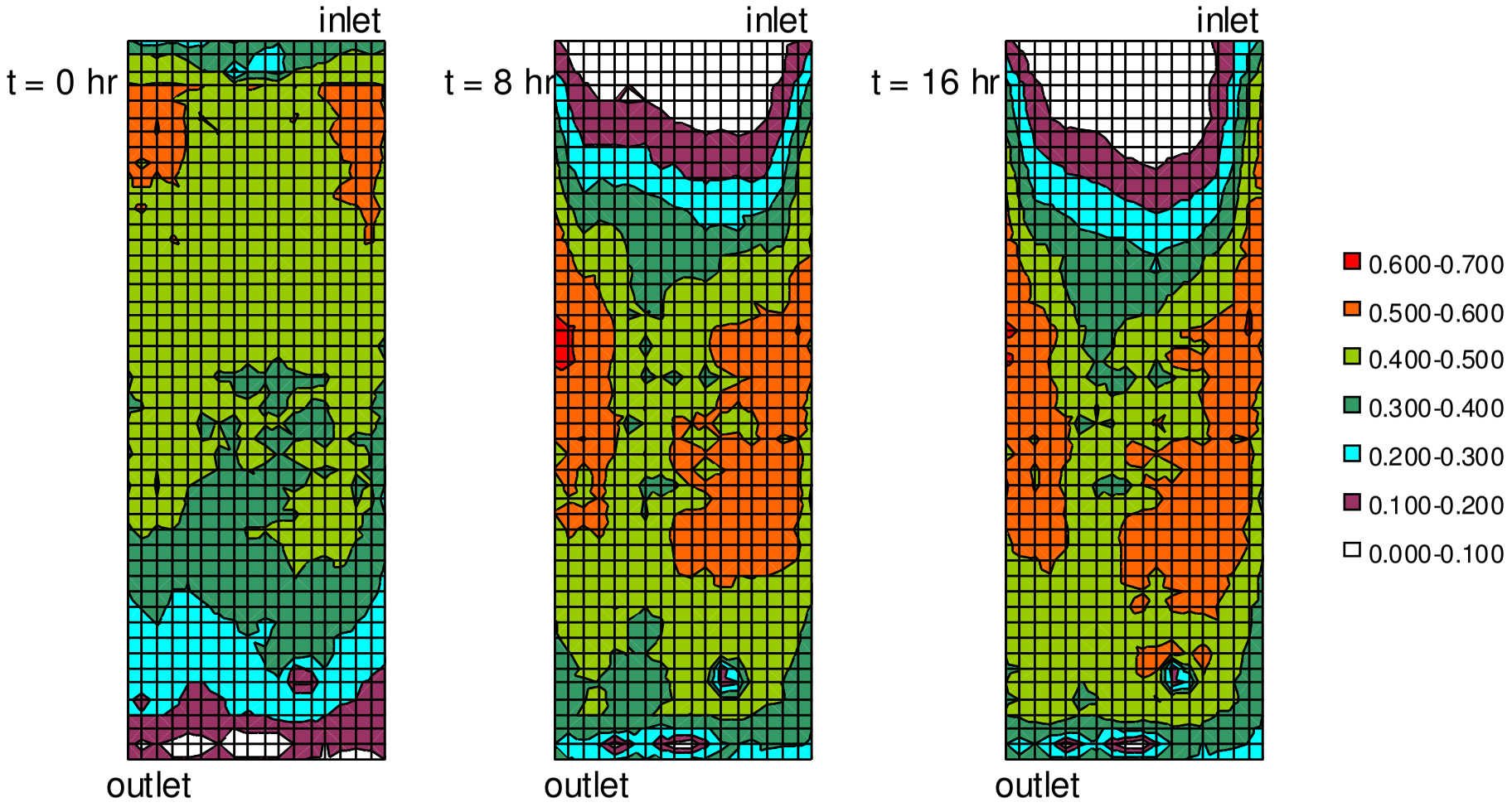
Results

- Dry cathode gas, 400 mA/cm^2



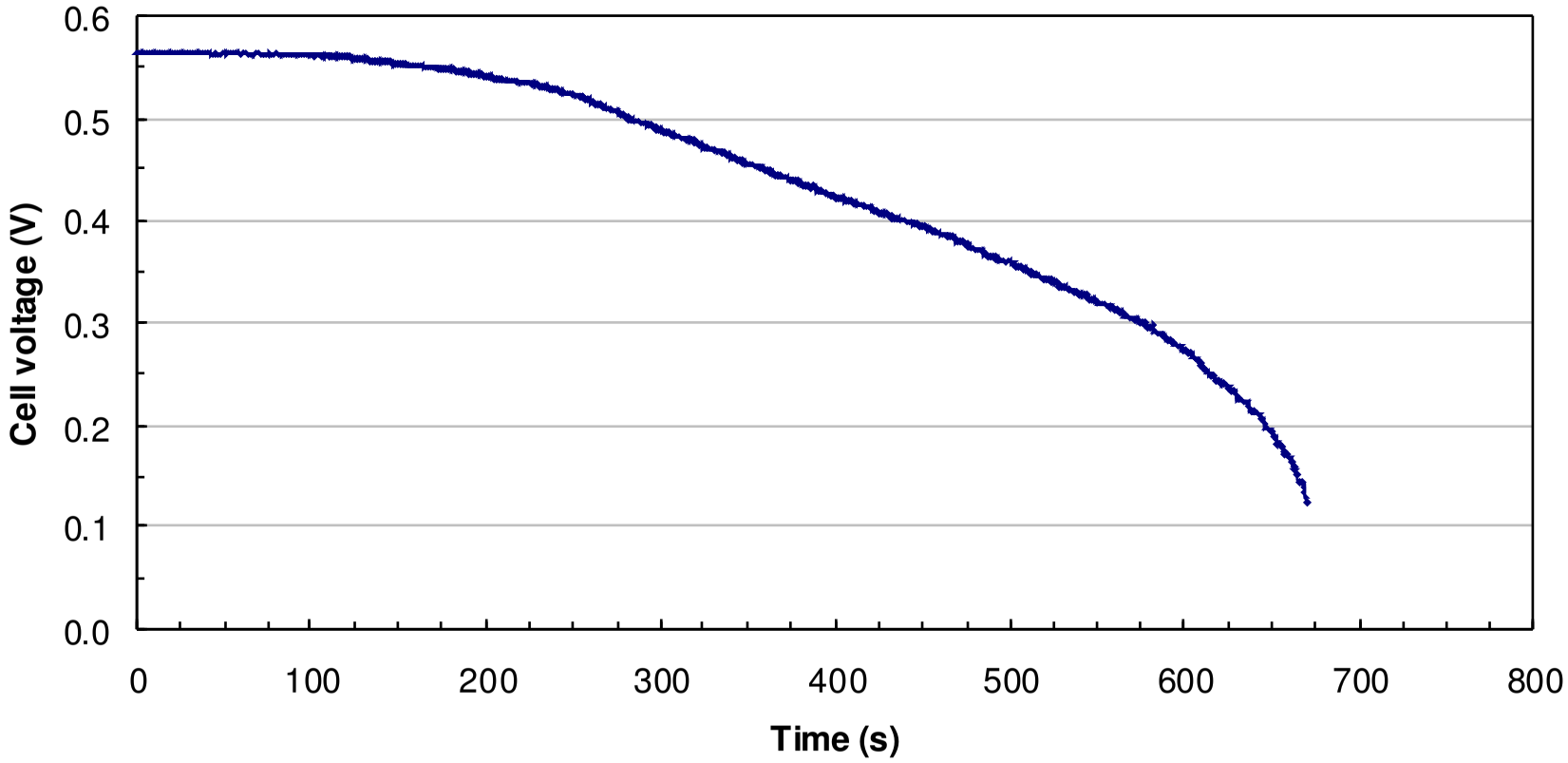
Results

- Dry cathode gas, 400 mA/cm^2



Results

- Dry cathode gas, 800 mA/cm^2



Results

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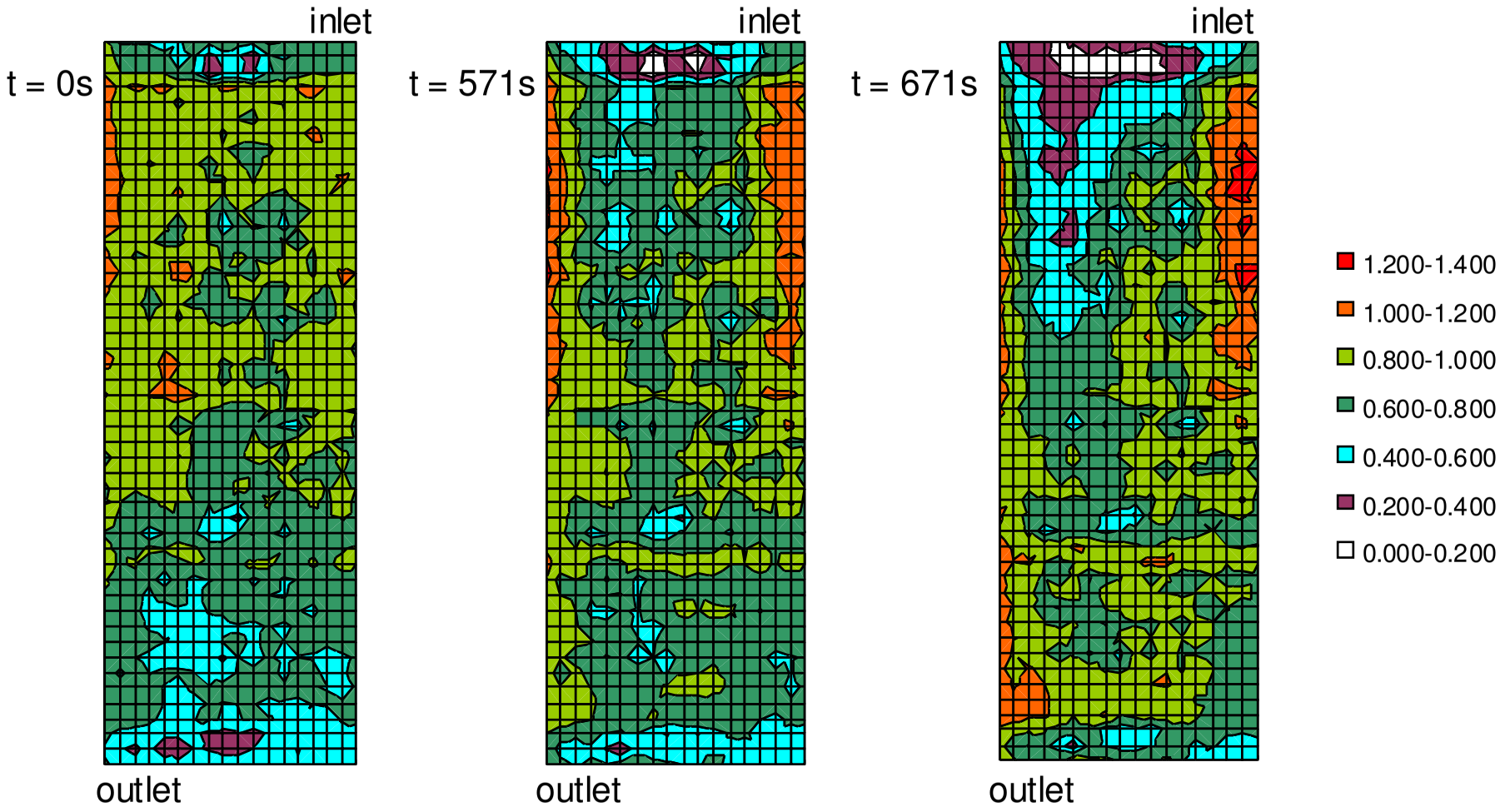
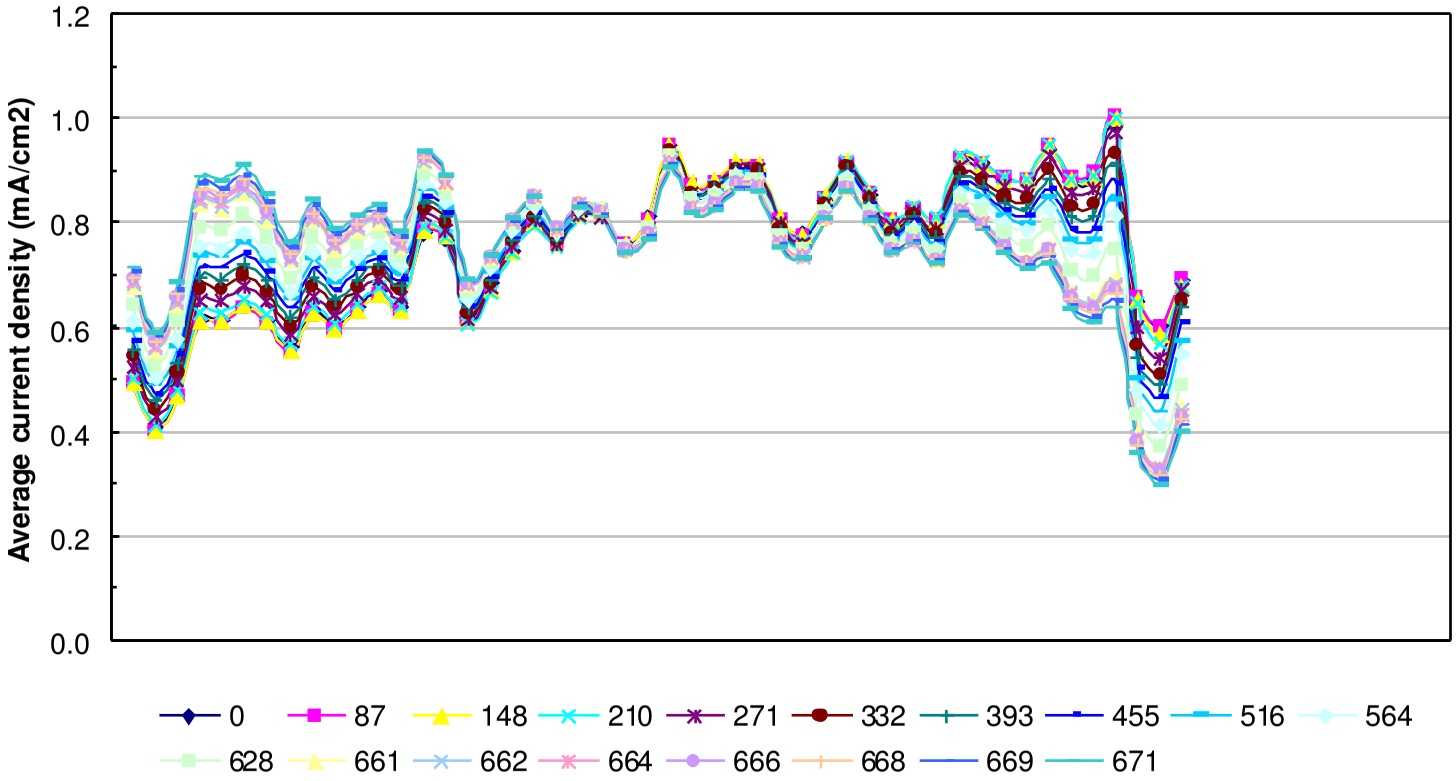


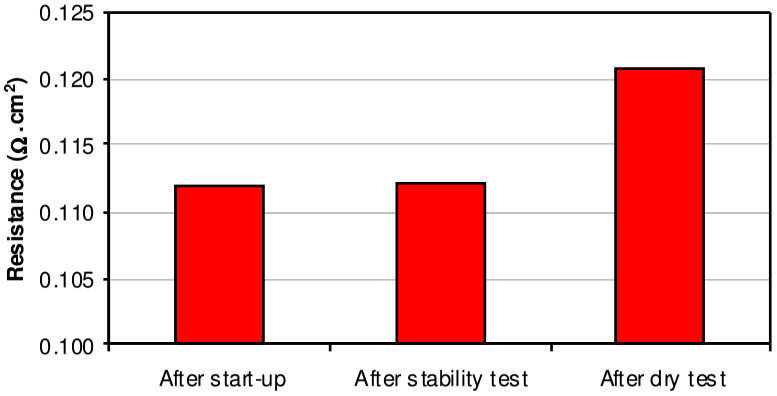
Results

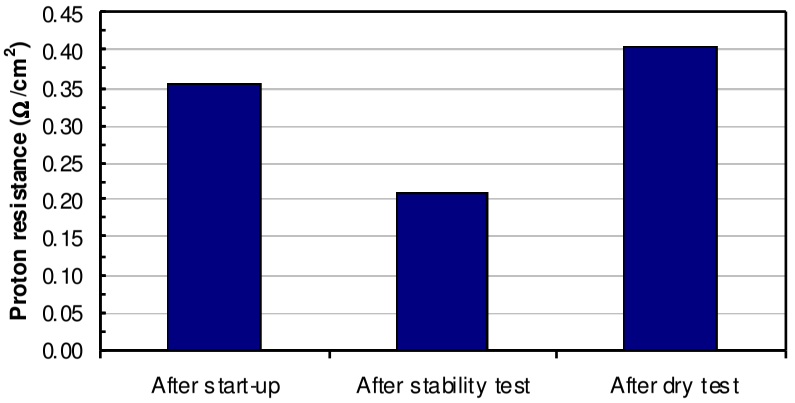
- Dry cathode gas, 800 mA/cm^2

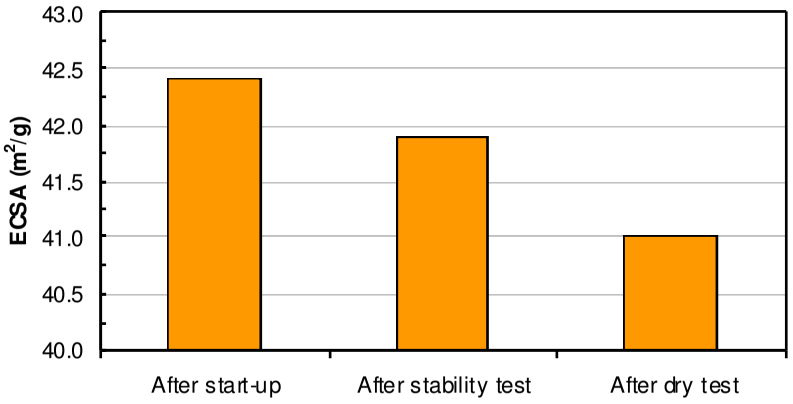


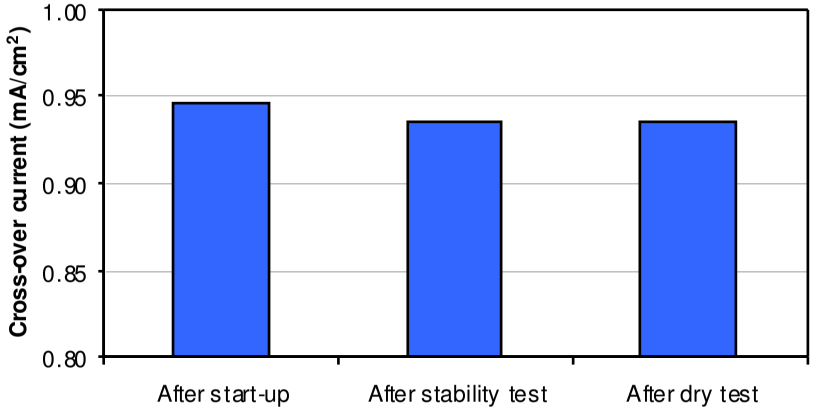
Results

- SEM analyses show no abnormalities
- No Fluor present in exhaust water



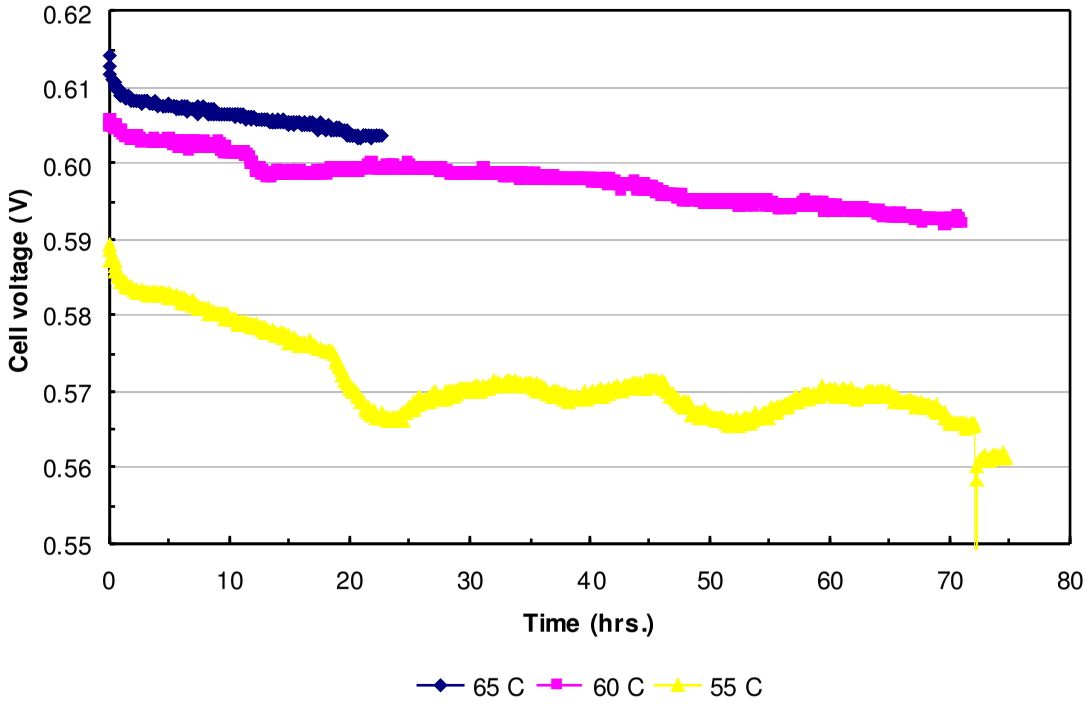






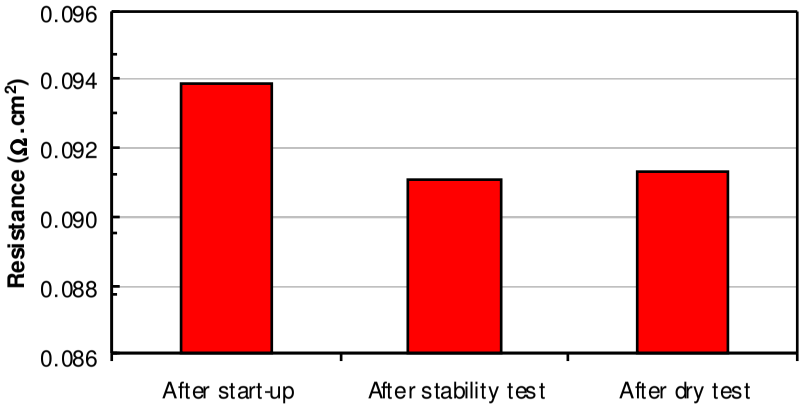
Results

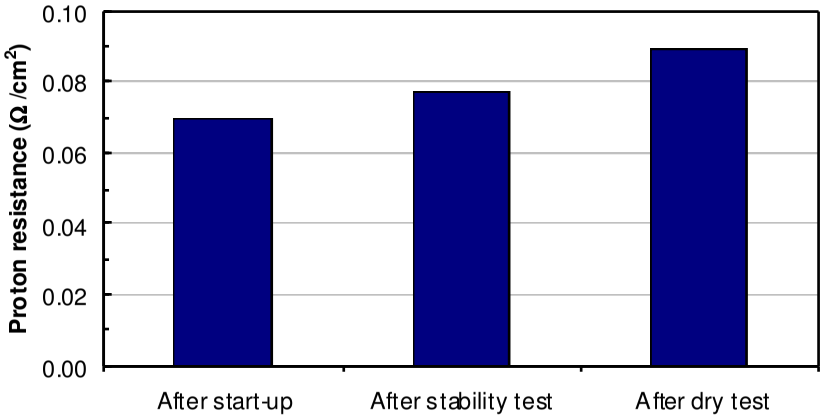
- Dry anode gas, 800 mA/cm^2

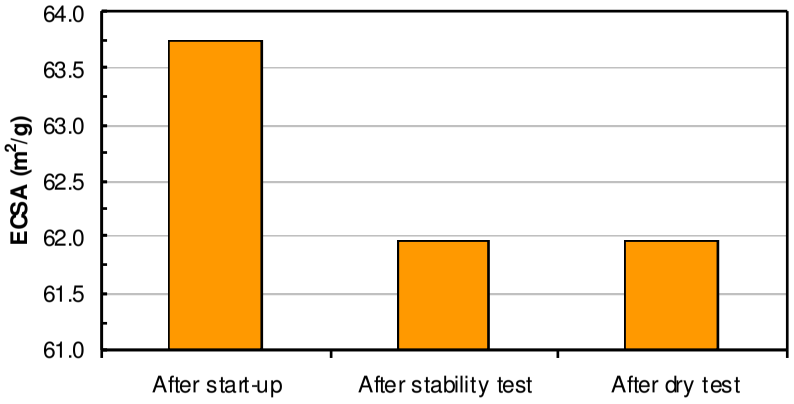


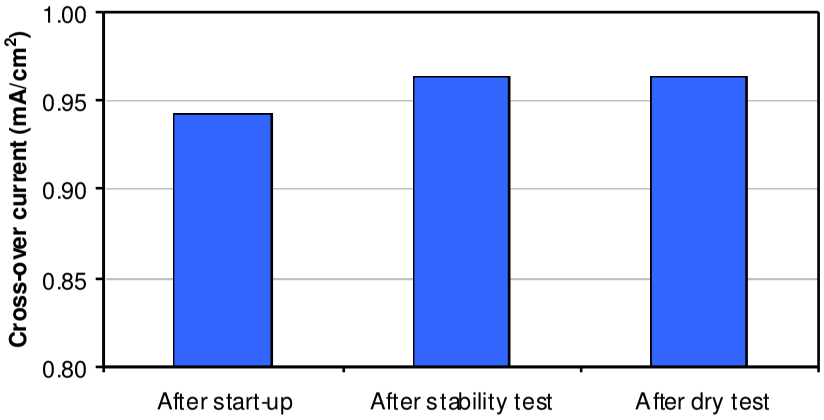
Results

- Sem analyses show some Pt in membrane
- No Fluor present in exhaust water







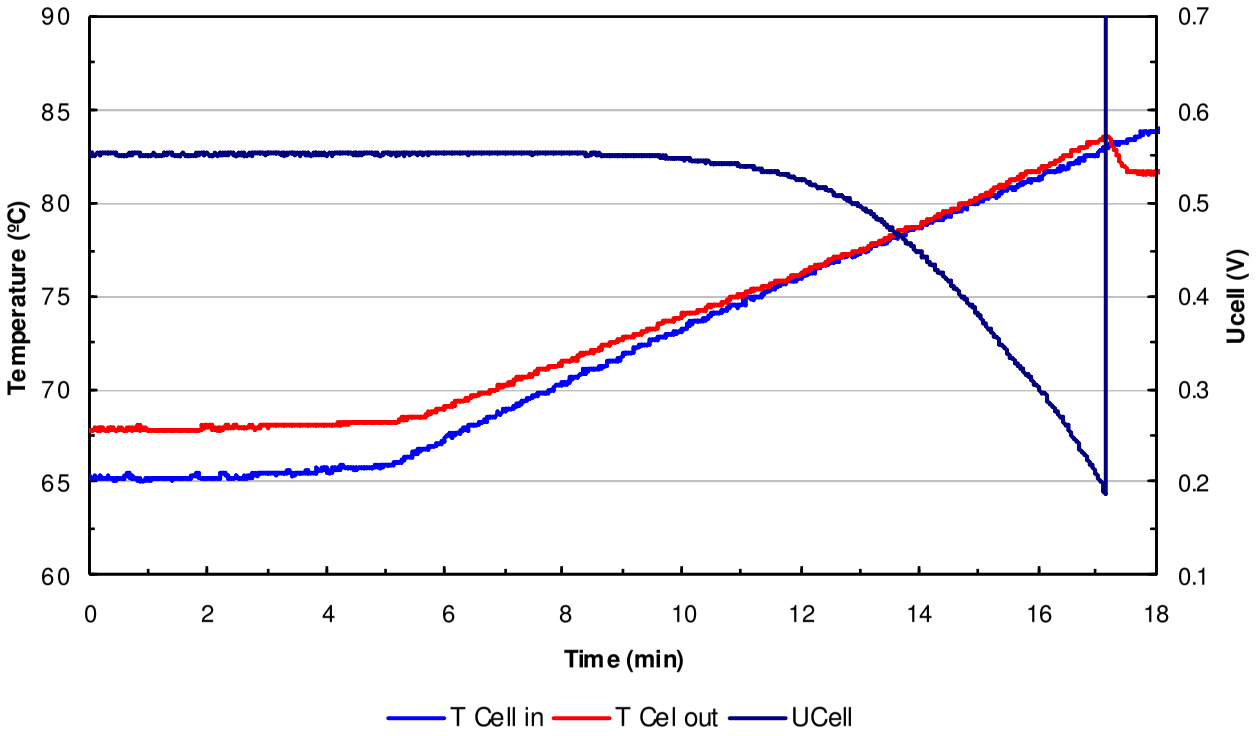


Results

- **Effect temperature excursion**

Results

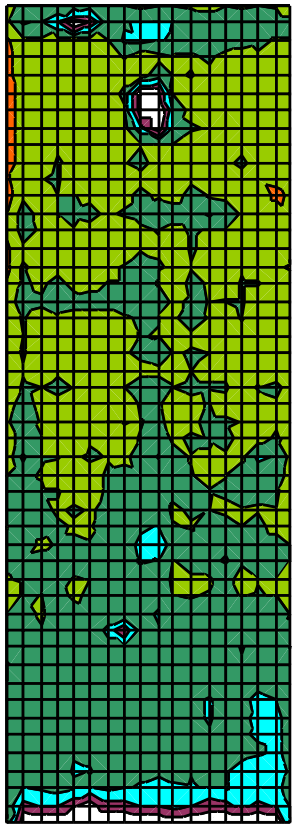
- Temperature excursion, 800 mA/cm^2



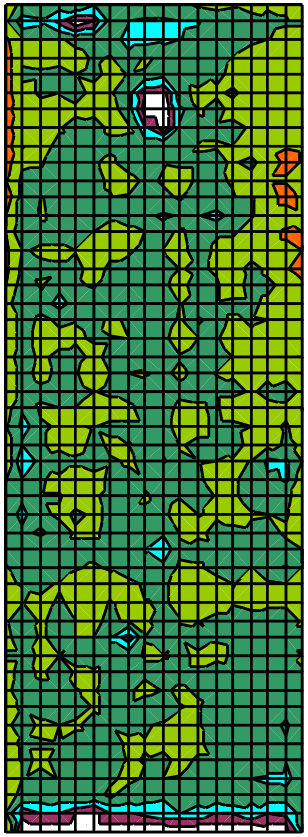
Results

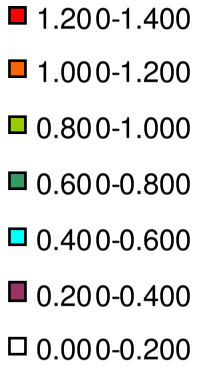
- Temperature excursion, 800 mA/cm^2

inlet



outlet





Conclusions

- A technique is available to measure the current density distribution on a scale of 400 cm^2
- Lowering the stoichiometry results in a tilting of the current density distribution
  - more and more current is being produced at the inlet region
  - this effect is most pronounced for the cathode.
- Dry air operation shows a rapid voltage decrease at a high current density
  - A tilting of the current density distribution is seen
    - at the inlet region the current density drops from 0.9 A/cm^2 to 0.6 A/cm^2
    - at the outlet region the current density increases from 0.9 A/cm^2 to 0.6 A/cm^2
- Dry air operation shows a slow voltage decrease at a low current density
  - A tilting of the current density distribution is seen
    - at the inlet region the current density drops almost down to zero
- Cell operation using non-humidified hydrogen only causes a slow cell voltage decrease, provided the cathode humidification temperature is above 55 ^oC.
- A temperature excursion leads to a rapid drop in cell voltage and an even distribution of the current

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