

Why extended temperature range?

➤ stack for automotive applications:

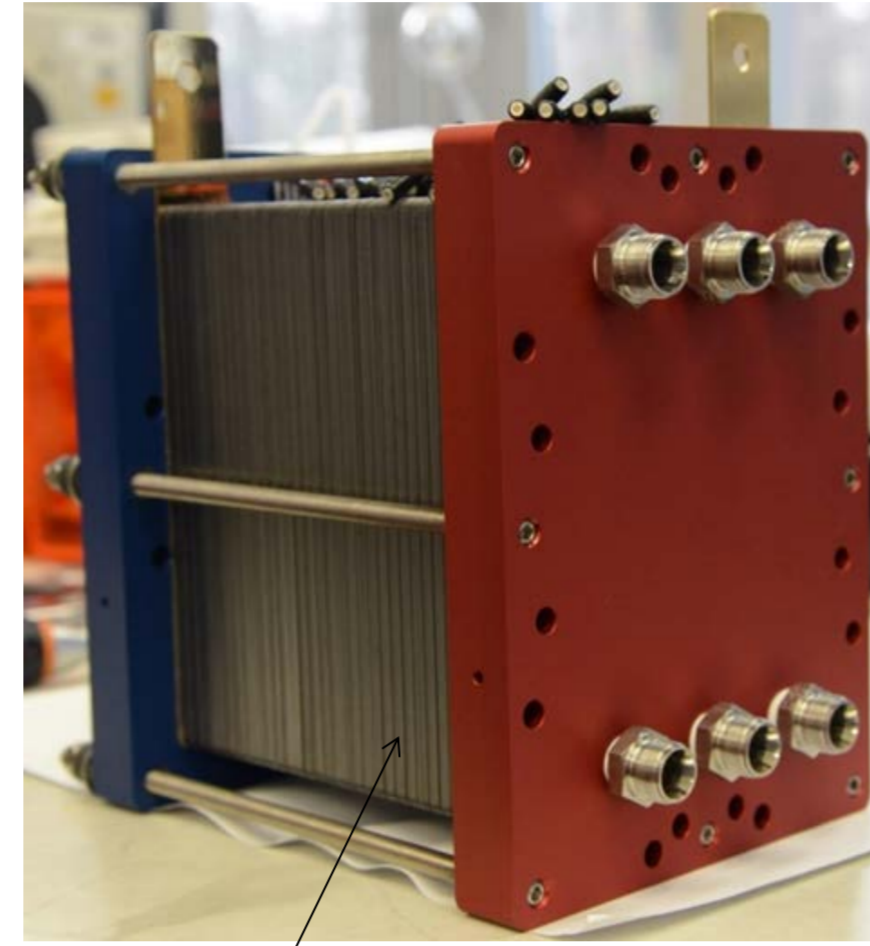
able to perform **transient operation** at high load even with critical cooling conditions (higher power required → higher heat production):

- long uphill drive
- driving in hot areas, e.g. deserts (reduced cooling)

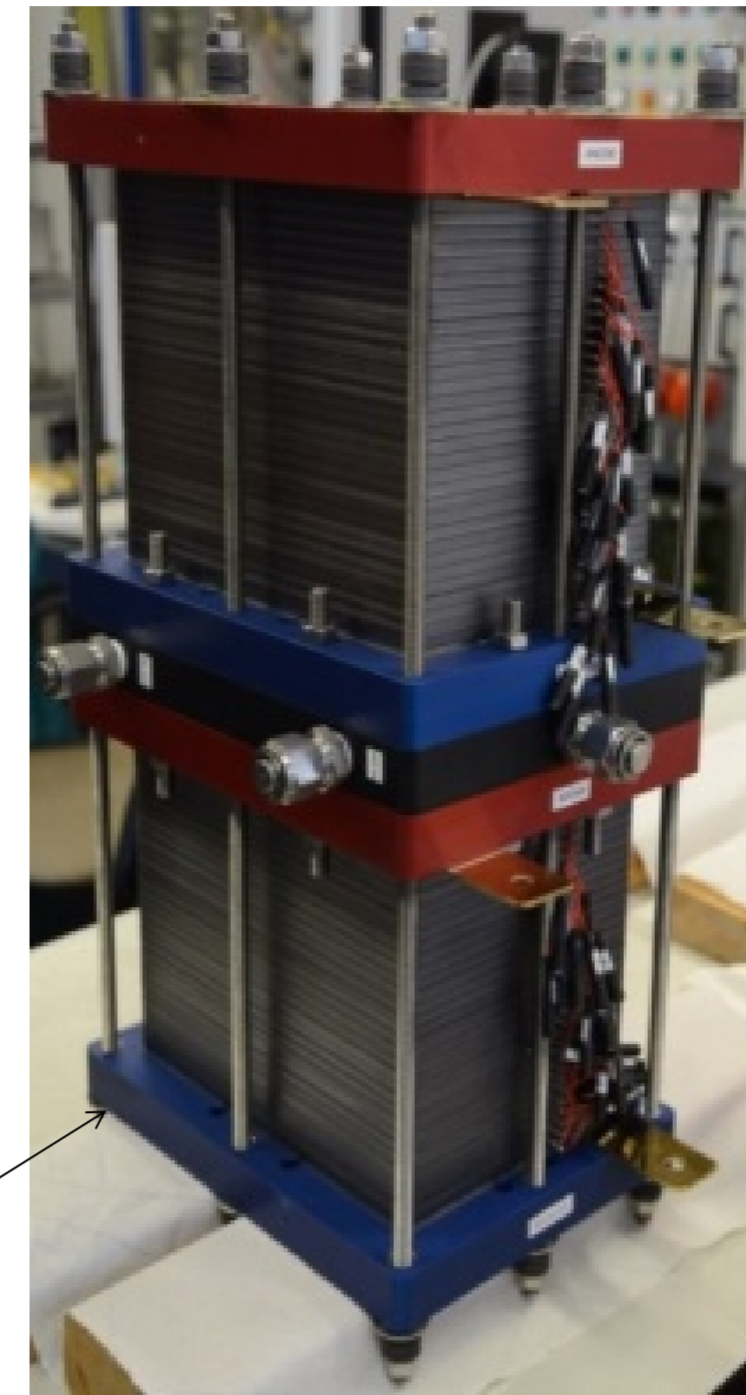
➤ downsizing of cooling system:

lower cooling power is necessary (increased heat dissipation) if higher stack temperature is allowed:

- shorter cooler operating time (energy/fuel saving)
- smaller cooler size (space/weight saving in vehicles)



stack module with 30 cells



full stack with 60 cells

T. Ruiu, A. M. Dreizler, J. Mitzel, E. Gülzow, J. Power Sources 303 (2016) 257-266.

Wide-temperature-range (WTR) stack goals

➤ development of a PEMFC stack:

- 2.5 – 5 kW_{el}
- 30 – 60 cells

➤ feasibility of WTR-conditions:

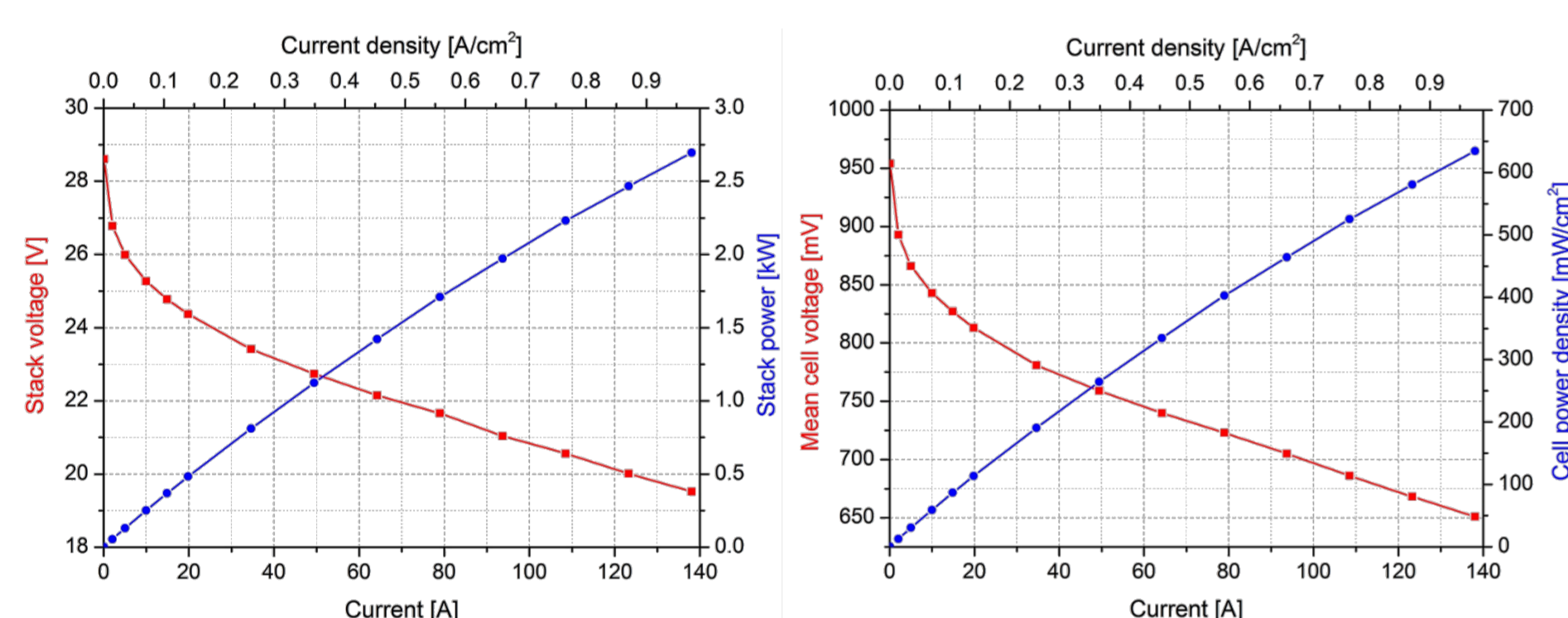
- extended temp. range **up to 120 °C**
- **20 temperature cycles** feasible
 - duration of each cycle: 65 min
 - aim: reversible maximum power loss at 120°C with unmodified humidification: 30 %

➤ durability test:

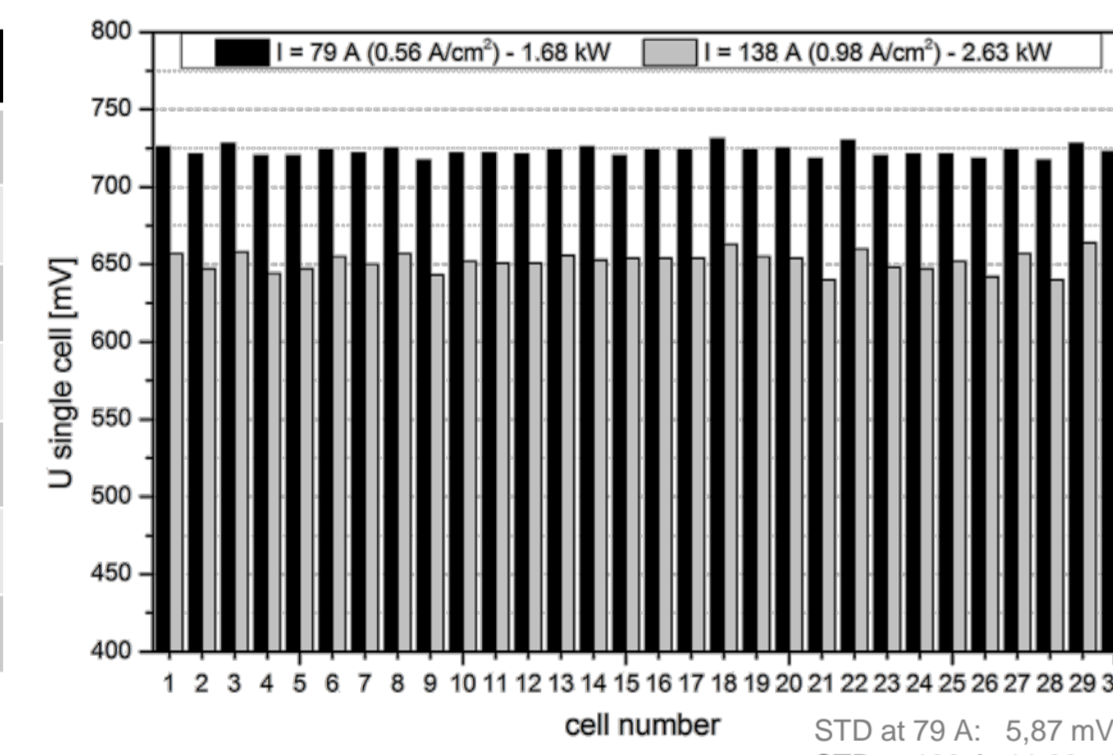
- long-term test over **1000 h**

Experimental results

Polarization curve (BoL)



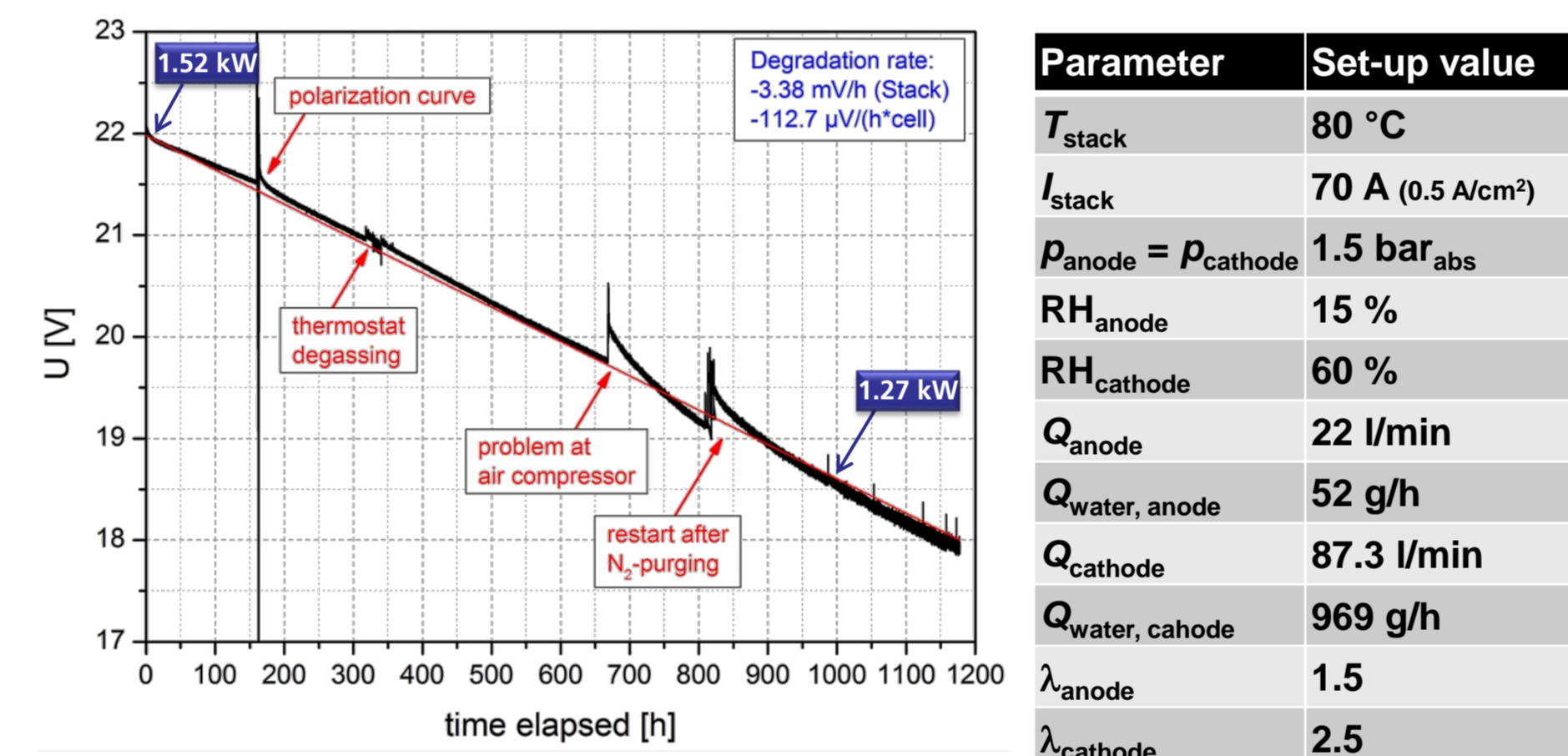
Parameter	Set-up value
T _{stack}	80 °C
p _{anode} = p _{cathode}	1.5 bar _{abs}
RH _{anode}	15 %
RH _{cathode}	60 %
i _{anode}	1.5
i _{cathode}	2.5
t _{dwell}	5 min



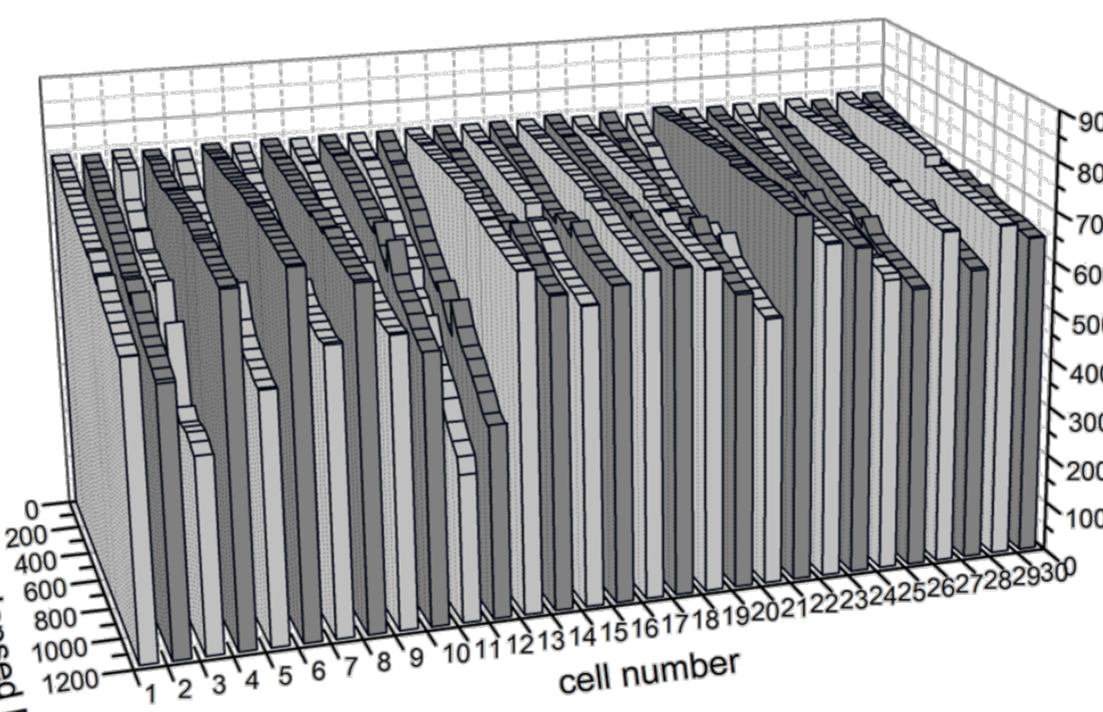
- high homogeneity of 30 single cell voltages
- all 30 cells are fed homogeneously with reactants

Long-term test

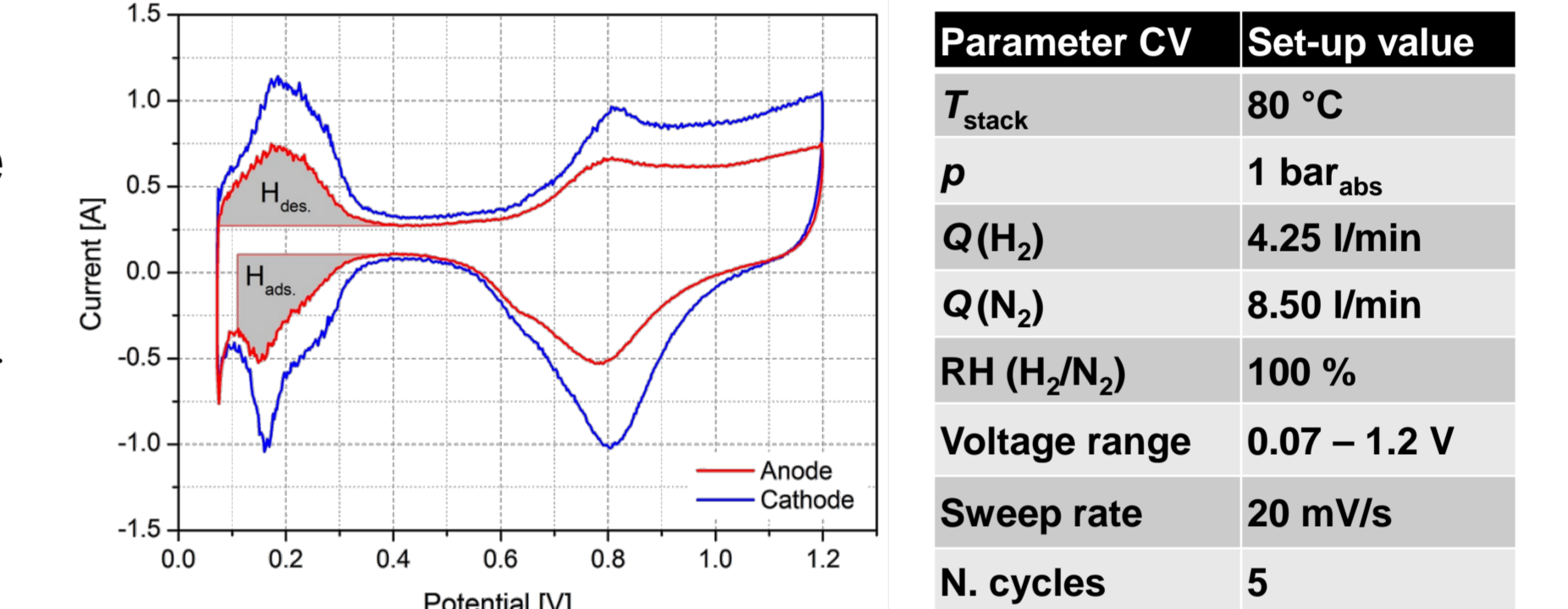
- 1200 h at 70 A: output power 1.5 kW_{el}
- degradation rate nearly constant: linear voltage drop
- 16 % power loss in 1000 h (ca. 250 W, 3.5 V) → 0.016 %/h (250 mW/h or 8.3 mW/(h-cell))



single cell voltage behaviour during long-term test at 70 A (0.5 A/cm²):

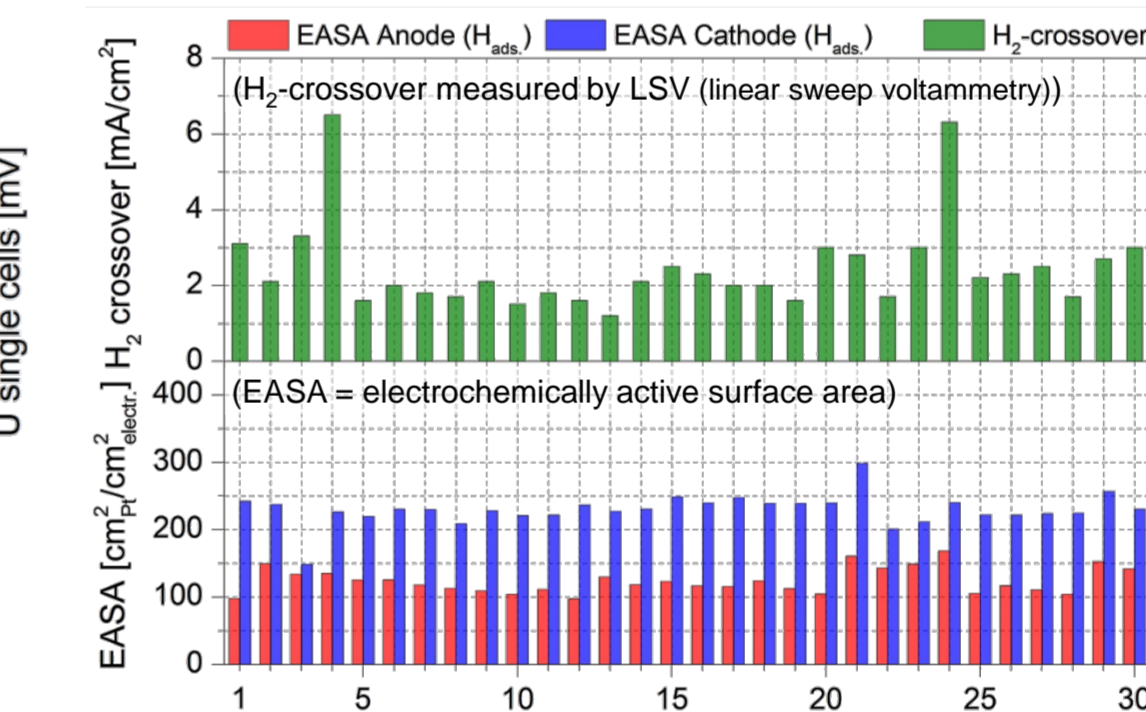


Cyclic voltammetry and H₂-crossover

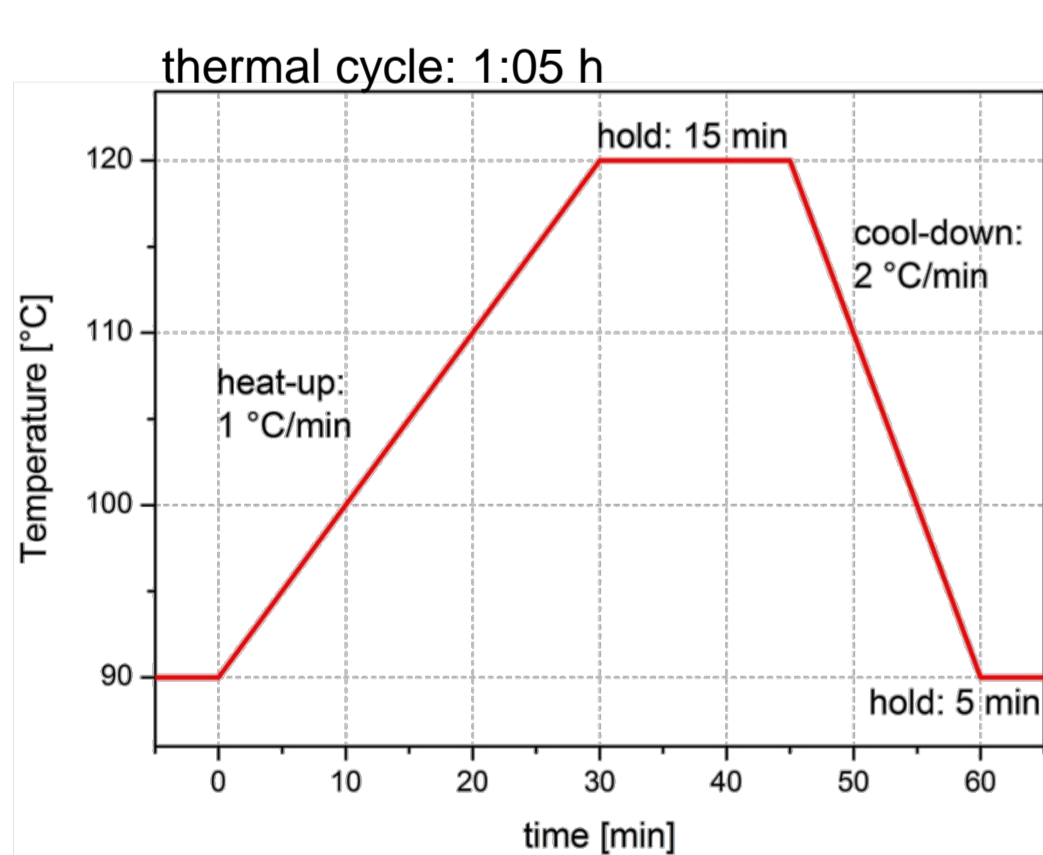


Aim: identify possible stressors responsible for performance loss:

- catalyst degradation → decrease of EASA by catalyst growth/washout
- carbon corrosion
- membrane degradation
- chemical/mechanical degradation



Thermal cycles 90–120 °C

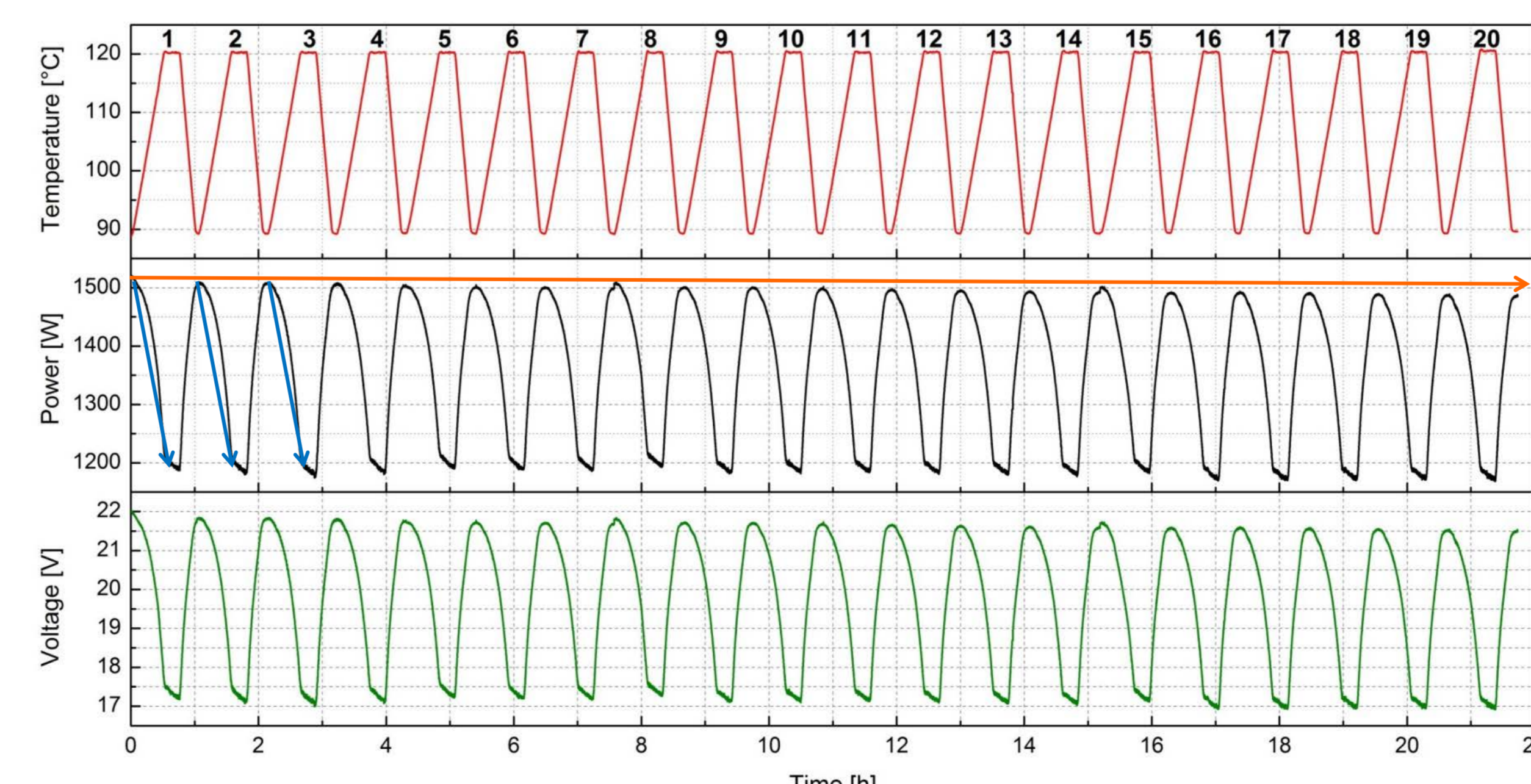


Parameter	lower limit	upper limit
T _{stack}	90 °C	120 °C
p _{anode} = p _{cathode}	1.5 bar _{abs}	
i _{stack}	70 A (0.5 A/cm ²)	
Q _{anode}	22 l/min	
Q _{water, anode}	907 g/h	
Q _{cathode}	87.3 l/min	
Q _{water, cathode}	2464 g/h	
RH _{anode}	100 %	35 %
RH _{cathode}	80 %	28 %
λ _{anode}	1.5	
λ _{cathode}	2.5	

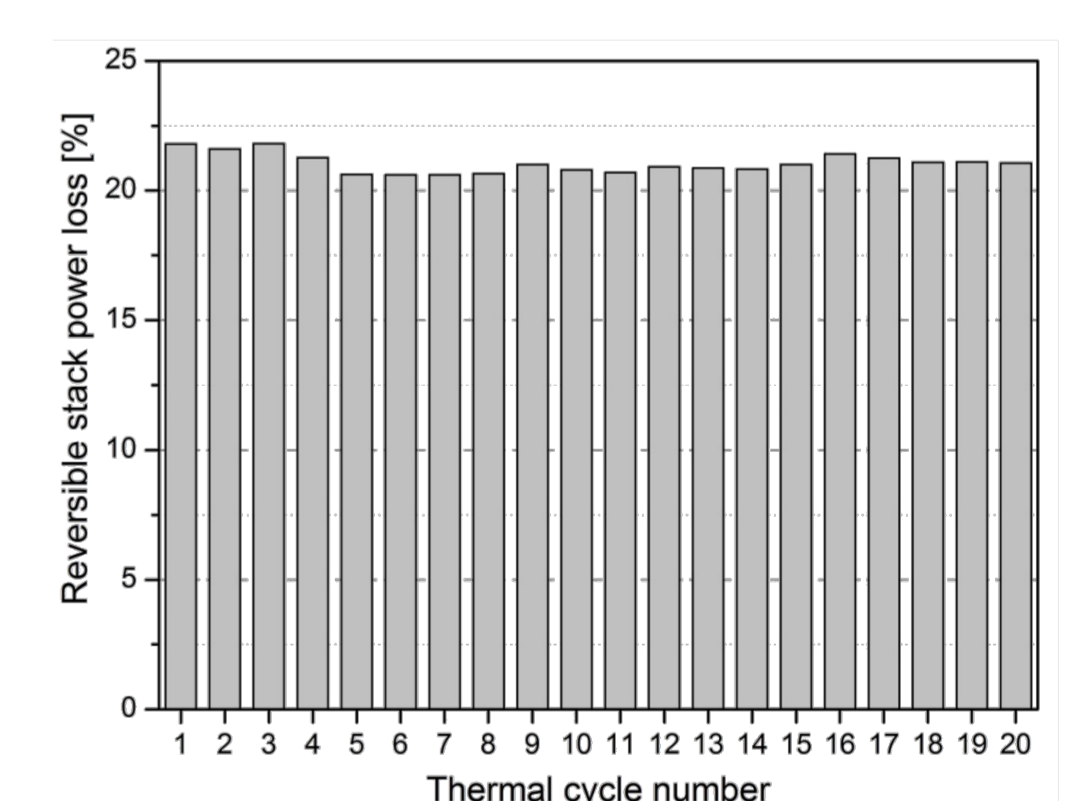
- 20 thermal cycles at 70 A (0.5 A/cm², 1.5 kW)
- cycle duration: 1:05 h → 45 min transient operation (90 → 120 °C) + 15 min cool-down (120 → 90 °C) + 5 min recovery (90 °C)
- gas humidification: on both sides 100 % at 90 °C (cycle start), then no variation
- goal: max. 30 % power loss within a cycle

Information obtained on:

- **reversible power loss within a cycle** → membrane drying
- **irreversible degradation** → stack stability over all cycles



Irreversible stack performance drop is small enough for automotive applications



Results:

- stable reversible power loss within a cycle: 21 ± 1 %
- irreversible stack power loss at 90 °C: 33 W in 22 h → < 0.1 %/h (1.5 W/h or 50 mW/(h-cell))
- good stack stability over all cycles

