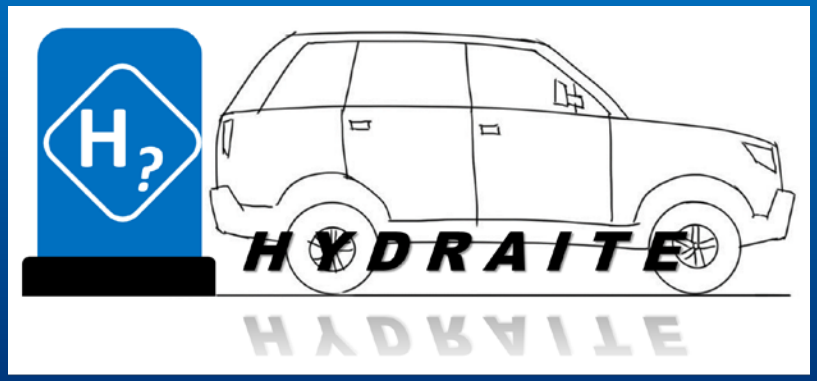


Challenges of hydrogen quality in fuel cell lifetime investigation

HYDRAITE 1st OEM workshop
March 7 and 8, 2018 – Ulm/Germany

Alexander Kabza et al

HYDRAITE Fuel cell impurity measurements

- Focus on PEMFC for automotive application on stack level with state-of-the-art MEA/CCM configuration.
- “Using the latest generation automotive stacks”
  (no single cell 25 or 50cm² hardware)
- Most realistic duty cycle and operational limits of the FC system.
- Investigation of low impurity concentration, e.g. CO down to 50ppb!
- Anode loop design

Challenge 1

HYDROGEN QUALITY

Hydrogen quality challenges

- **Hydrogen quality measurement (ISO 14687-2):**
  Not available so far for all HYDRAITE project partners. Best equipment currently at NPL. ZSW and ZBT will follow within Hy-Lab!

- **Liquid hydrogen or “pure” hydrogen from cylinders like 6.0 or 7.0**
  Due to the boil-of liquid hydrogen storage makes only sense for more than e.g. 80 tons per year. H_2 6.0 and 7.0 not possible for stacks!

- **Purifiers or filters**
  Purifiers or filters are available with different technologies, small filters are ok for small amount of hydrogen. For several kg/hour hydrogen purifiers or filter are quite costly, also during operation!

- **Gas mixture / calibrant preparation**
  E.g. 50ppb CO in H_2 does not exist as a premixed calibrant or reference gas. That means this mixtures need to be prepared individually!

ZSW solution: In-house analytics

The annual hydrogen consumption at ZSW is around 10 to 12 tons.

Not enough for liquid hydrogen, therefore we have the worlds biggest gaseous tank with 95 m³ (volumetric) and 45 bar (max).

To ensure the hydrogen quality typically two times a month samples are analyzed, or on specific request. Besides N_2 and Ar nothing suspicious was detected so far!

Purifiers/filters are used for specific tests!

Date	Ar / ppm	O2 / ppm	N2 / ppm	CH4 / ppm	CO / ppm	CO2 / ppm
2017-02-06	0,45	0	49,7	0,06	0,00	0,00
2017-02-14	0,45	0	52,2	0,04	0,00	0,00
2017-02-23	0,49	0	50,4	0,00	0,00	0,00
2017-02-28	0,46	0	48,7	0,02	0,00	0,00
2017-03-06	0,46	0	49,0	0,04	0,00	0,00
2017-04-26	4,30	0	37,0	0,05	0,00	0,00
2017-05-11	2,80	0	40,8	0,07	0,00	0,00
2017-05-17	6,80	0	96,1	0,11	0,00	0,00
2017-05-24	6,63	0	94,9	0,10	0,00	0,00
2017-06-20	8,07	0	73,2	0,13	0,00	0,00
2017-06-29	10,53	0	86,9	0,12	0,00	0,00
2017-07-06	12,34	0	90,5	0,10	0,00	0,00
2017-07-11	12,09	0	88,2	0,10	0,00	0,00
2017-07-20	12,55	0	88,8	0,14	0,00	0,00
2017-07-26	10,57	0	80,3	0,15	0,00	0,00
2017-08-02	10,94	0	78,9	0,12	0,00	0,00
2017-08-14	10,88	0	78,5	0,10	0,00	0,00
2017-08-21	11,14	0	95,7	0,12	0,00	0,00
2017-08-29	13,79	0	90,7	0,10	0,00	0,00
2017-08-30	13,51	0	87,8	0,10	0,00	0,00
2017-10-06	13,28	0	5,3	0,04	0,00	0,00
2017-10-11	13,58	0	5,7	0,04	0,00	0,00

Challenge 2

MOST REALISTIC DUTY CYCLE AND TEST CONDITIONS

Fuel Cell Vehicle versus Fuel Cell Test Station

Fuel Cell Vehicle = Real aging
There are FCVs on the road, stacks are operated there most realistic, stacks do age most realistic. Stack operating conditions are very realistic, but partly "un-controlled" and highly heterogeneous. Perfect data recording, but confidential!*

Stack on Test station
There are stacks on test stations, operated under well controlled and artificial operating conditions and profiles, but maybe not very realistic. Perfect data recording, highly reproducible (if you know what happens in one hour, you also know what happens in 1000 hours).

From both tests we can measure (or calculate) the irreversible voltage loss as a measure for stack aging in µV/OpHr.

H2020 ID-FAST
Project ID: 779565

But:

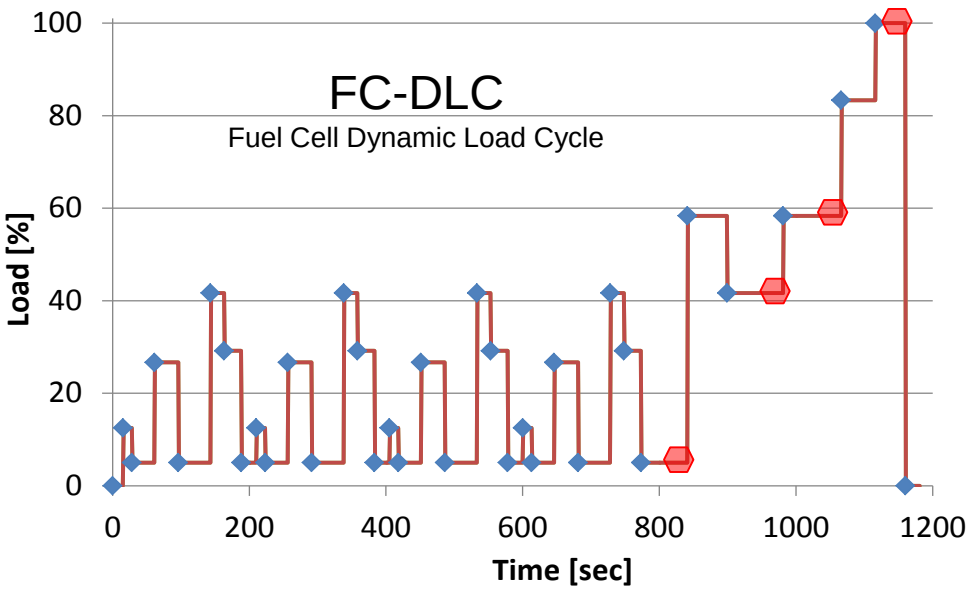
- How to compare vehicle data with test stations data?
- What are the events that influence lifetime most significantly?
- What is the impact of hydrogen quality?

* Accumulated data available by NREL (DOE project ID FC-081)

Stack durability on test station

Shortstacks are operated under FC-DLC with reference conditions, including well-defined start/stop, cold soak, and sometimes also with anode recirculation.

This is the test that we consider as “realistic test” that can be performed on a “state-of-the-art” commercial available fuel cell test station.

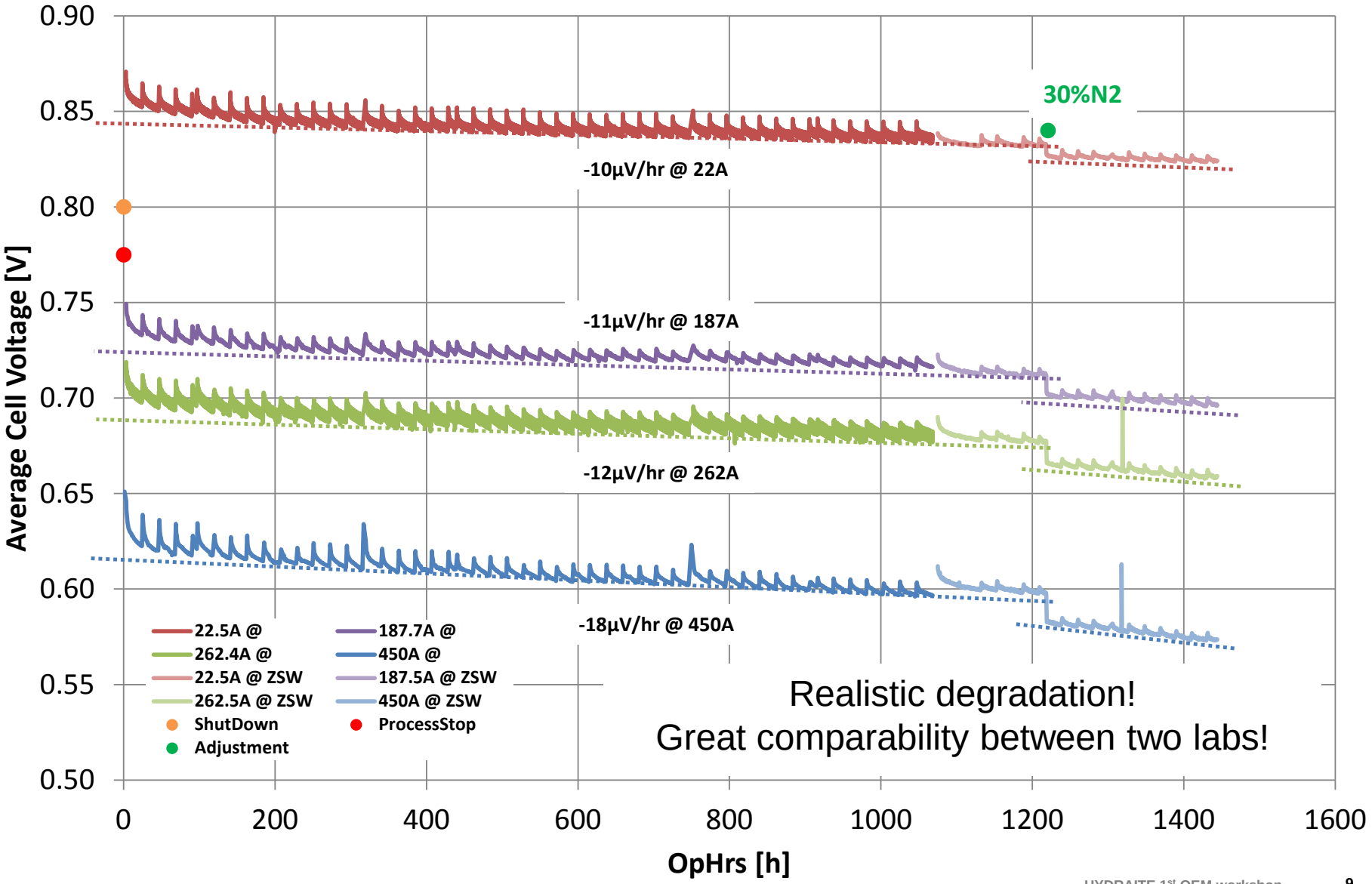


The FC-DLC is defined by 35 load steps. The average load is ~28% of full load (100%). Duration is about 20min.

Investigation:

Voltage level at specific load steps plotted over time.

Automotive stack durability testing example



Challenge 3

IMPACT OF TEST STATION

Hydrogen quality challenges

- Test stations from **different suppliers with different designs** may influence test results. A **good understanding** about the impact of different test stations design is needed.

- All sensors and actuators need to be **calibrated** carefully before starting lifetime experiments. This sound simple, but its an intensive procedure.

- It makes a lot of sense **to switch one stack** between two or more test stations. This gives a better understanding about the impact of the individual test station, at least on the stack performance.

- Especially the **gas humidification is something special**! Depending on the humidifier setup this may have a significant impact on the dynamic behavior of test stations. From the HYCORA project its known that the automatic refill of DI water may cause in anode air bleed. We recognized CO_2 spikes after cathode humidification refill.

Hydrogen quality challenges

- Calibration, calibration, calibration!!! A lot of work for 25 test stations!
- Compare test stations with same stacks (Round-robin)!
- Operate stacks in parallel on one test station or use (if possible) identical test stations.

Challenge 4

TIME, STATISTICS, DATA MANAGEMENT

Time, statistics, and data management

- Lifetime investigation is **time-consuming**!
- **Conditioning:** We have seen stacks where the conditioning was NOT finished after 200 OpHrs. In this case we need 500 or better 1000 OpHrs to get reasonable lifetime results.
- **“Einer ist keiner!”** (One is nothing!)
  To investigate the significance of tests more than one experiment is required; and three are better than two!
- The hydrogen quality may **depend on the batch**. Trailers can be refilled at different locations.
- With typical sampling rates of 1 Hz every lifetime experiment generated a **huge amount of data** that needs to be stored, analyzed and visualized!

ZSW solutions and considerations

- If possible, any **experiment is repeated** at least twice!
- Frequent **hydrogen quality measurements** are performed to minimize the risk of negative impact due to hydrogen batch, especially during lifetime investigation.
- **Fully automated script controlled test stations** are supposed to operate unattended 24/7 to collect as much data as possible.
- **Database** is used to store test data (~40,000 test hours in 2017).
- **Very standardized data investigation methods are applied.**

HYDRAITE lifetime investigation

- A reasonable amount of tests is required for fuel cell impurity measurements.
- A good understanding of test stations impact is needed to compare test results from different partners.
- There is a strong demand for hydrogen quality measurement at different project partners.
- We have to accept that different stack designs with different equipment (GDL, CCM/MEA, etc.) may have an impact to test results.

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Thank you for your attention

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