Hydrogen Fuel Quality

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Project ID: SCS007

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Overview

Timeline

- Project start date: 10/1/06
- Project end date: 9/30/11
- Percent complete: ~80 %

Barriers

- Barriers addressed
  - I. Conflicts between Domestic and International Standards
  - N. Insufficient Technical Data to Revise Standards

Budget

- Total project funding: $1,950K
  - DOE share: 100%
  - Contractor share: 0%
- Funding received in FY10: $450K
- Funding for FY11: $450K

Partners/Collaborators

- ISO TC 197/WG 12 members
- University of Hawaii/HNEI
- University of Connecticut
- University of South Carolina
- Clemson University
- SRNL
- NIST
- NREL
- ANL

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OUTLINE

- **Relevance: Background and Objectives**
- **Approach/Strategy:**
- **Technical Accomplishments**
  1. Experimental Set-up
  2. Testing Results/Findings: MEAs (Commercial Suppliers)
     - Hydrogen Sulfide-H_2S, Carbon Monoxide-CO, Ammonia-NH_3, and Mixture
  3. Initial Results with lower loadings
- **Future Work**
  1. Continue contaminant testing with 2015 targeted Pt loadings
  2. Determine tolerances with lower loadings
  3. Present data as results are completed

Relevance

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Objective:

To help determine levels of constituents for the development of an ANSI and international standard for hydrogen fuel quality (ISO TC197 WG12).

For the past 5 years, open discussions and/or meetings have been held and are still on-going with OEMs, Hydrogen Suppliers, other test facilities from the North America Team and International collaborators regarding experimental results, fuel clean-up cost, modeling, and analytical techniques to form a common consensus with respect to an 'international fuel standard'.

Technical Approach/Strategy

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- Provide data and analysis to the international effort to determine the levels of non-hydrogen constituents in support of the development of an International Standard for H_2 Fuel Quality
- Test the critical constituents (NH_3, CO, and H_2S)
  - Isolated and combined at various conditions
- Present data and have open discussions at ISO TC197 Working Group 12 Meetings
- Solicit guidance from leading industrial experts

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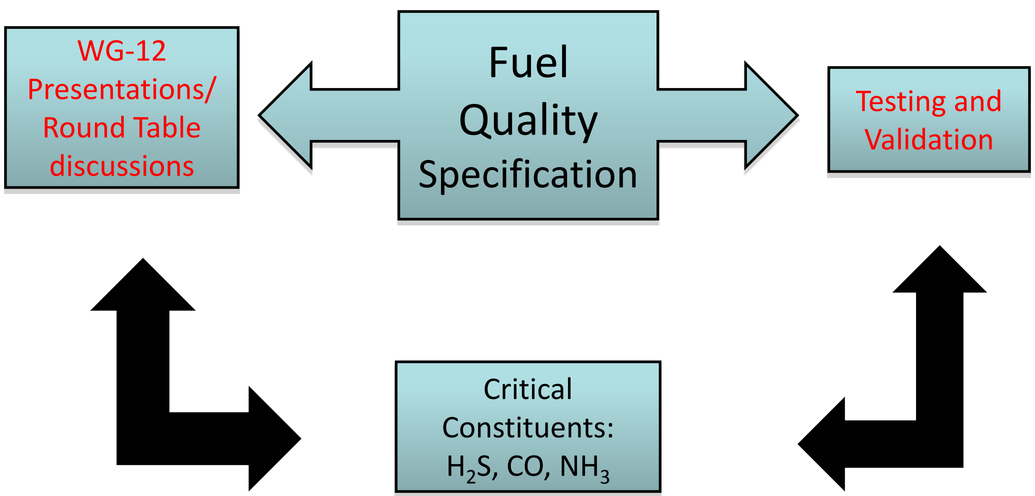
Technical Results & Accomplishments
Experiment Details

- Fuel Cell: 50 cm^2 Active Area
- Gas Diffusion Media: SGL 24 BC
- Calibrated MKS flow controllers
- Certified Impurities (Scott Specialty Gases)
- Electrolysis-grade H2/Air(oiless-compressor)
- *Focus Impurities: H_2S, NH_3 and CO*

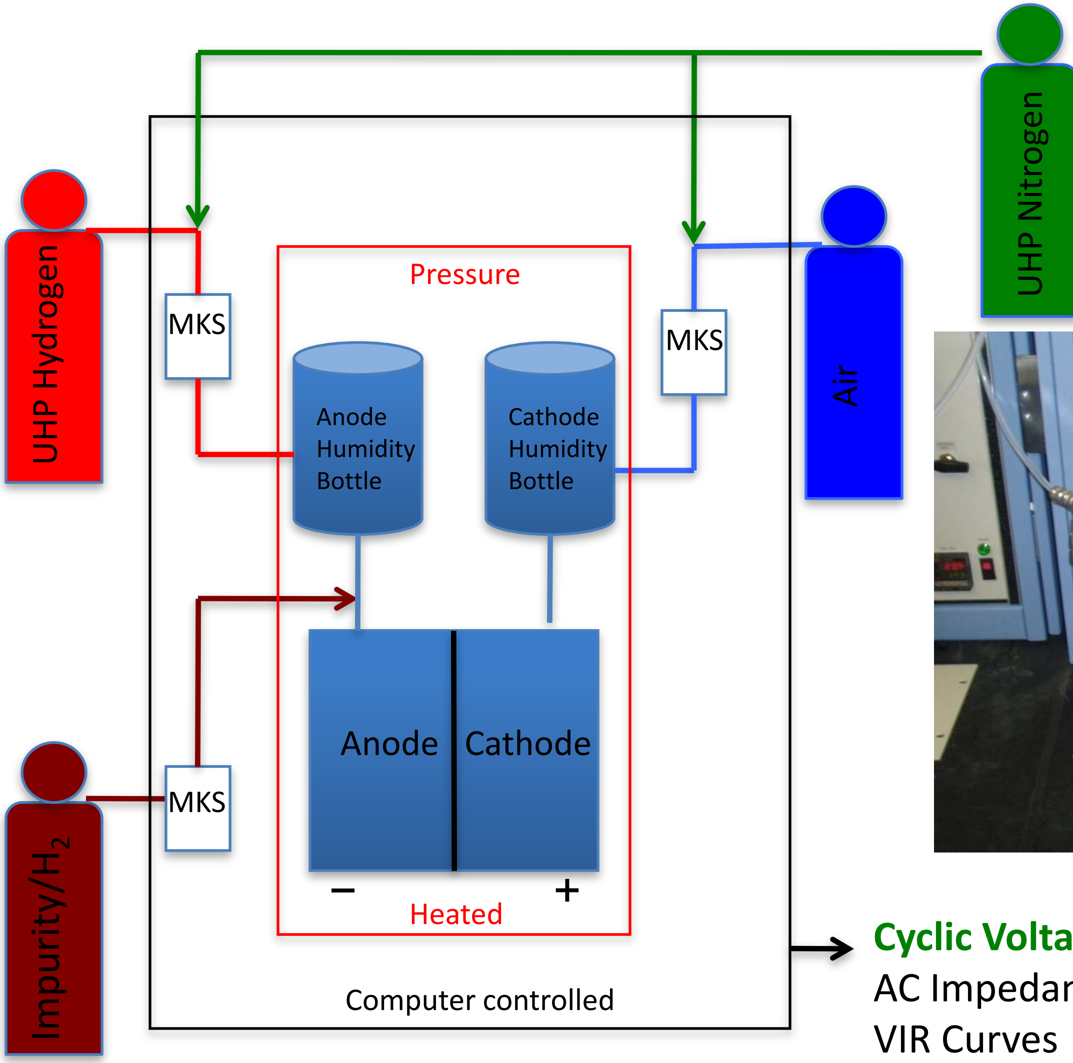
Hydrogen Fuel Quality Test Apparatus



Current Fuel Specifications Levels
NH_3: 0.1 ppm
H_2S: 0.004 ppm
CO: 0.2 ppm

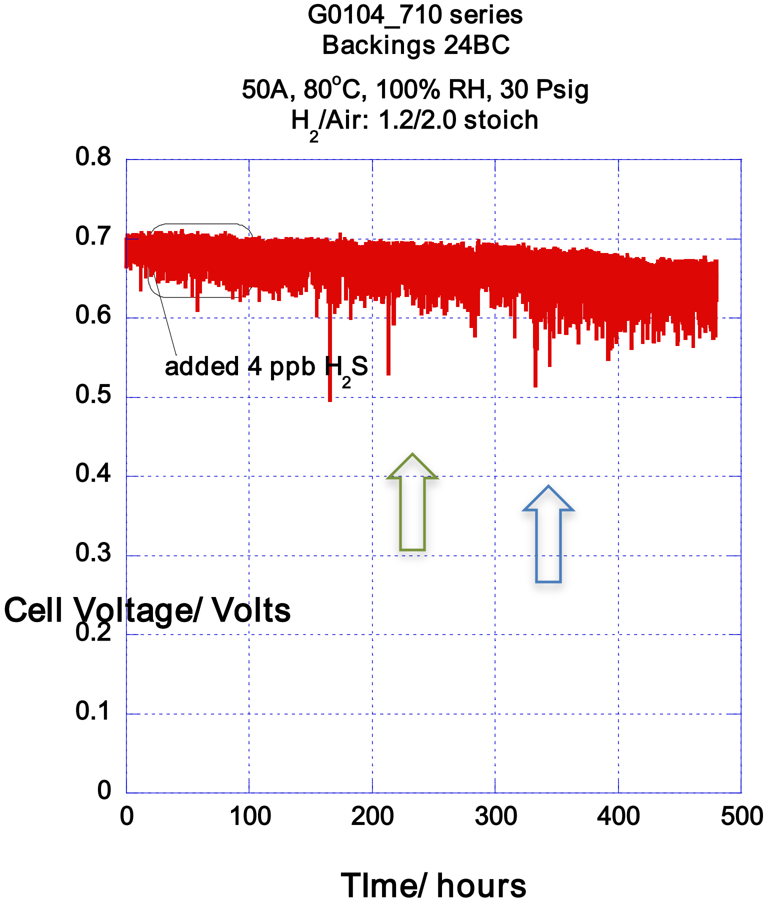
Technical Results & Accomplishments
Experiment Set-Up

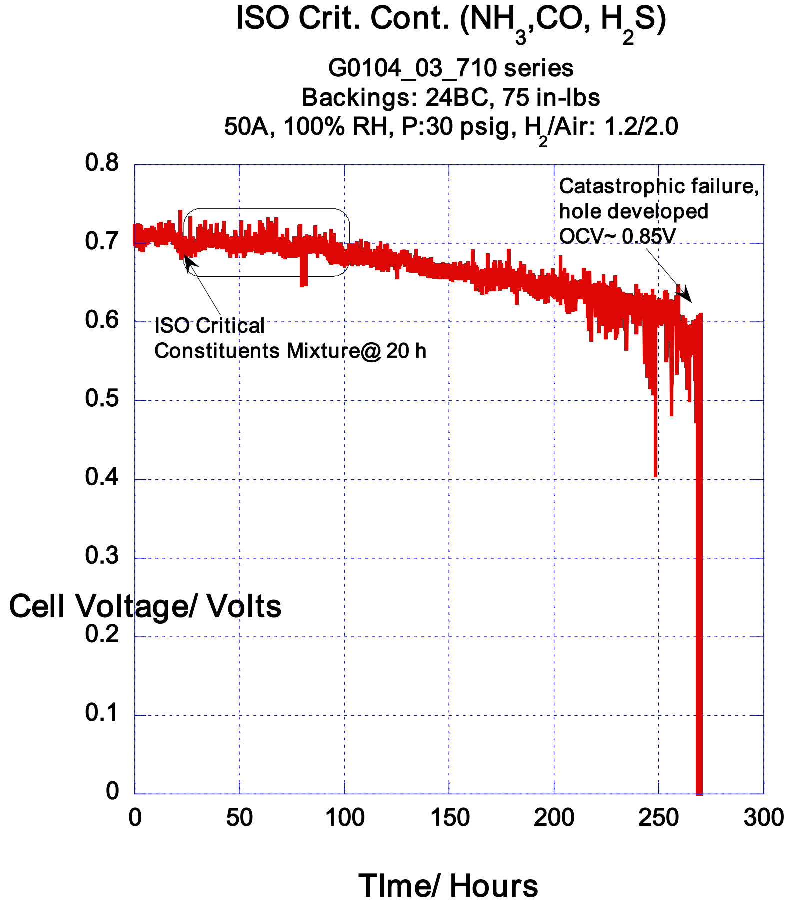
Fuel Cell Mode/or CV mode



Cyclic Voltammetry
AC Impedance
VIR Curves
Duration Test

2010 Highlights/Findings





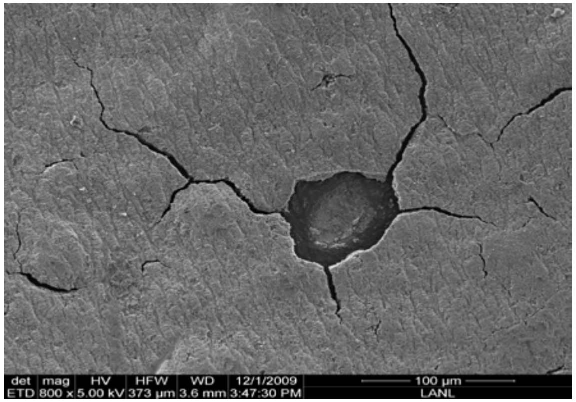
Slower poisoning onset, Higher operating Voltage

- good for H_2S tolerance
- *4 ppb H_2S for short term may be tolerable*

But if accumulation occurs these result will differ, the decay rates increases with time. (i.e. 0-100h, 100-200h, 200-300h)

Thinner membrane-bad for NH_3 tolerance

- durability issues?



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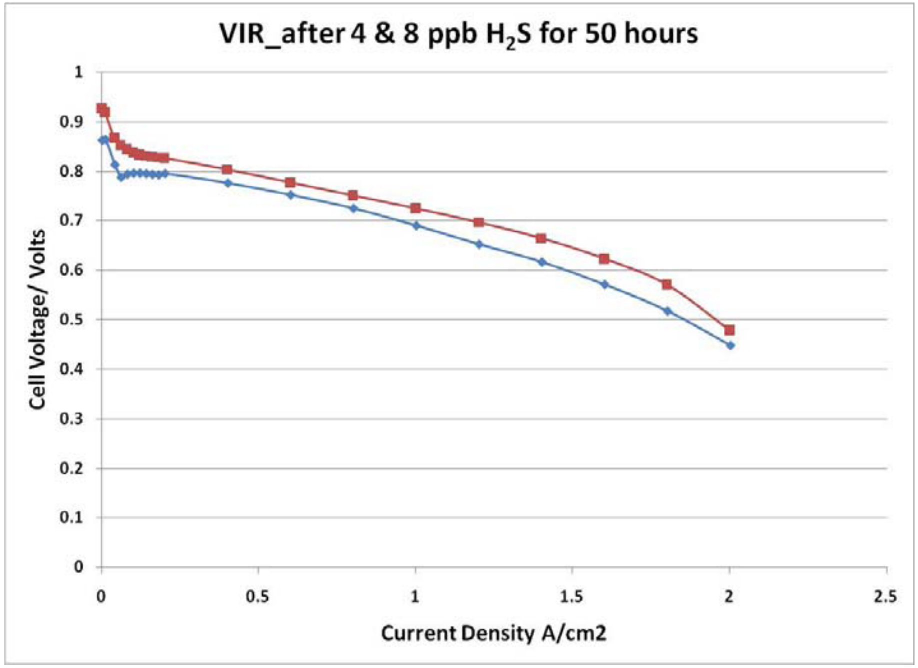
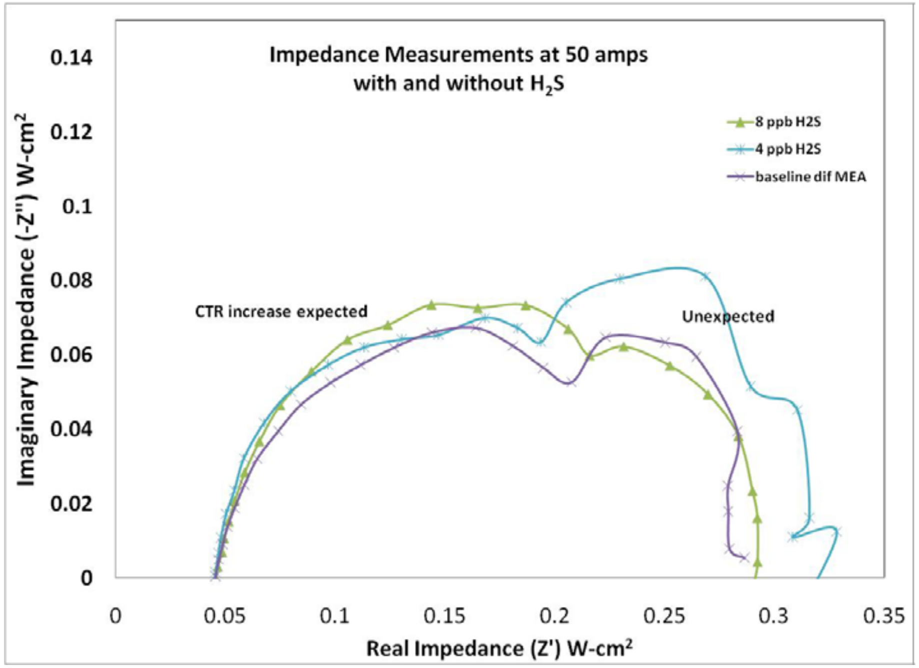
Fuel Cell Testing-Hydrogen Sulfide **2011 results**

What we know about H_2S? Previous results showed at 4 ppb we're tolerant for short term. But what happens as we increase concentration. Here, we report VIRs and AC impedance.





Losses become more evident at the higher H_2S concentration. CVs show a larger coverage for the higher concentration. Also, we observed an expected increase in CTR as illustrated in the impedance spectra.

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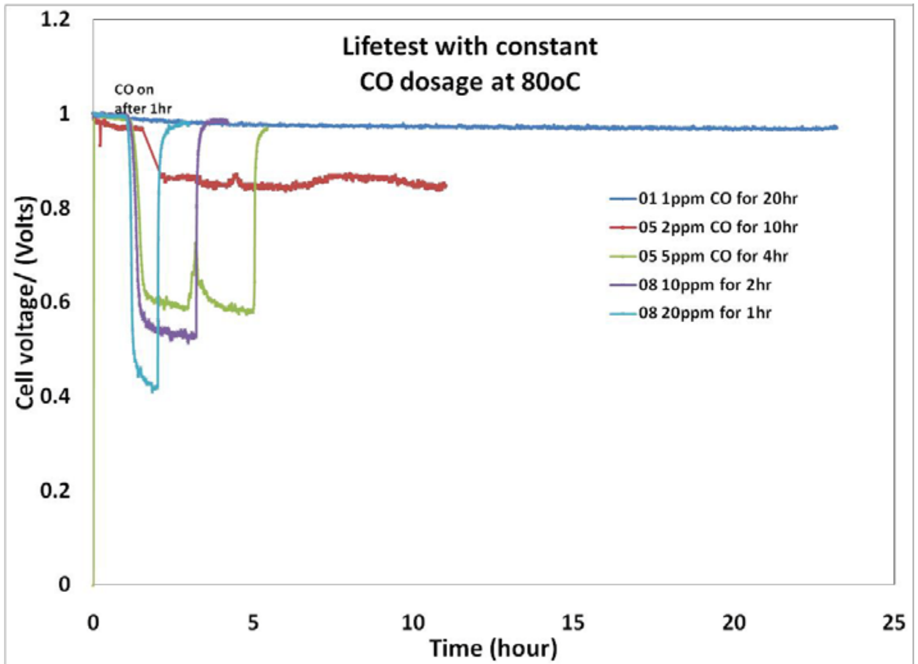
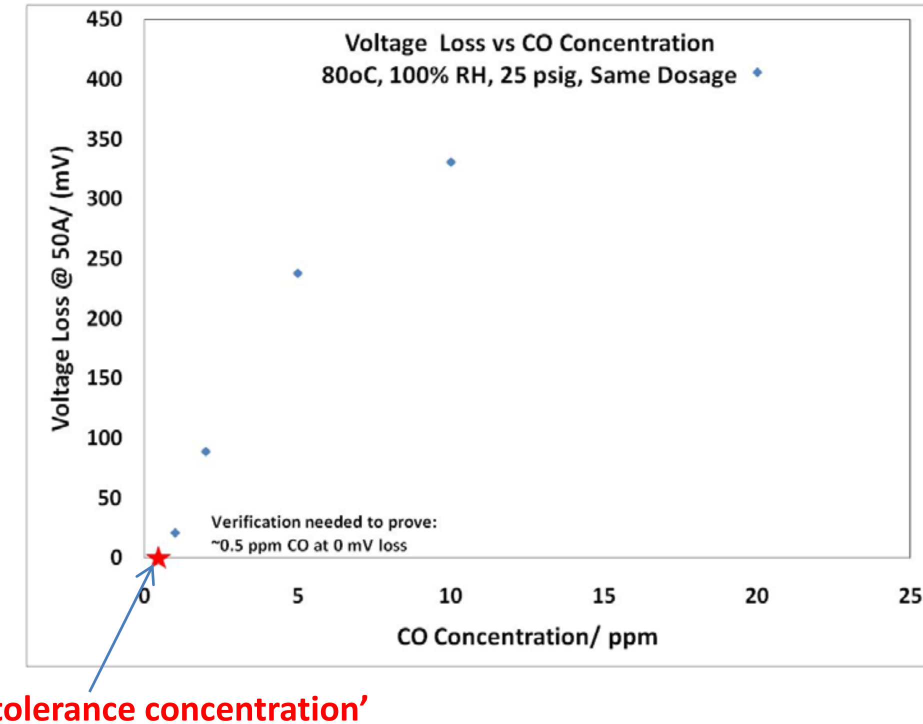
Test were run with 100 and 200 ppb CO, no losses were observed. We set-up experiments to Determine CO tolerance using same CO dosage and extrapolating to 0 mV loss at the 'tolerance concentration'.



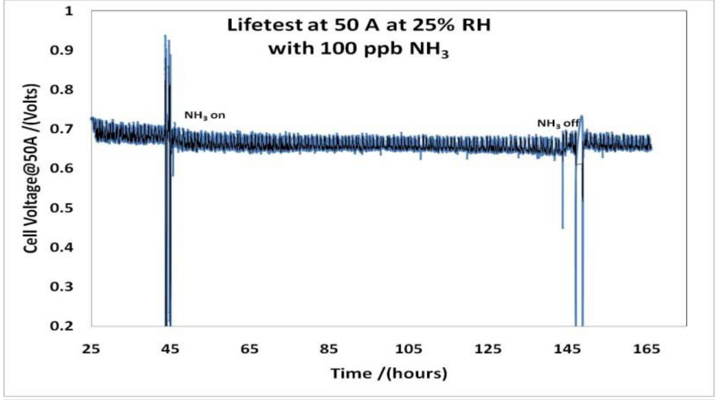


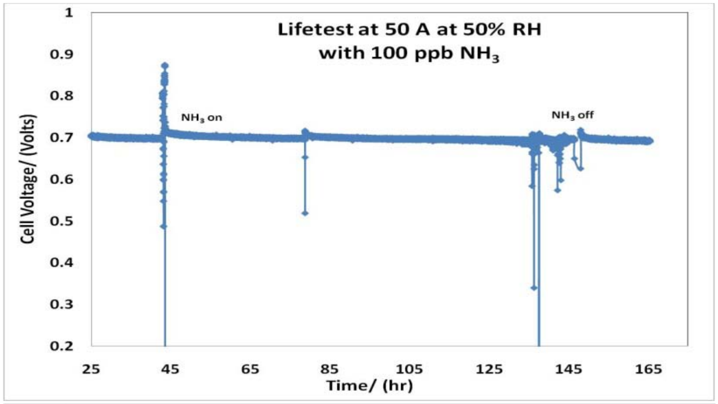
Results indicate the 'Common MEA' could **tolerate ~ 0.5 ppm CO** for at least **40 hrs**. We have started testing for confirmation. Also, note we expect CO tolerance to change as cell temperatures and anode catalyst loadings are lowered.

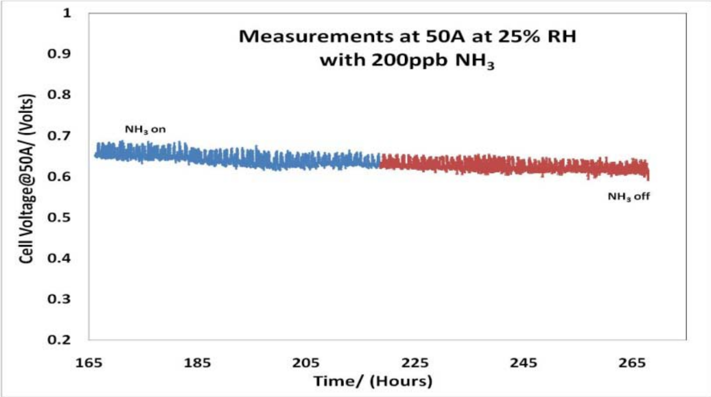
Fuel Cell Testing- Life Test Results NH_3

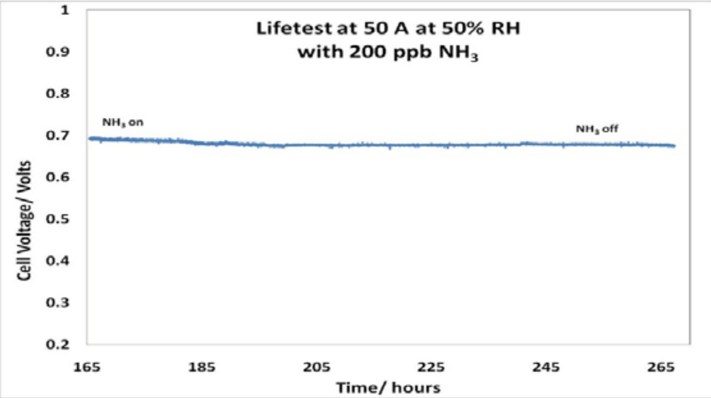
Results shown reflect the impact of NH_3 as a function of RH and concentrations in the anode feed for 100 h.

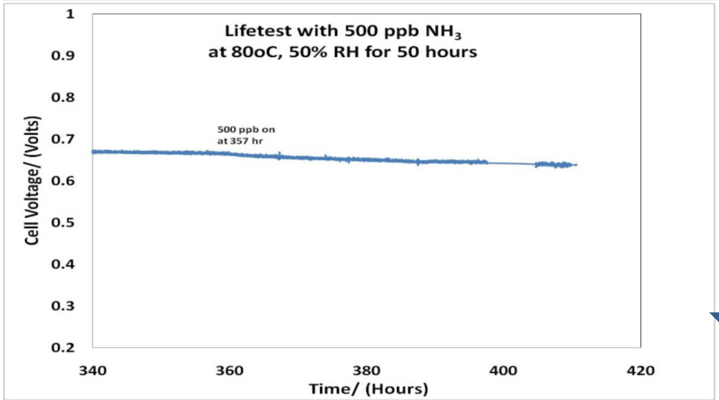
Increasing RH → Decreases losses











Increasing Concentration ↓ Increases losses

Test at 25% RH showed the losses for 100 and 200 ppb were 24 and 36 mV, while 50% RH were 8 and 17 mV. At 500 ppb NH_3 performance dropped 33mV in 50h.

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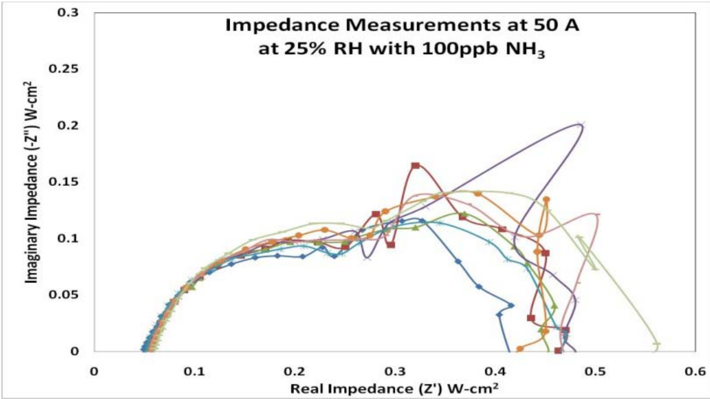
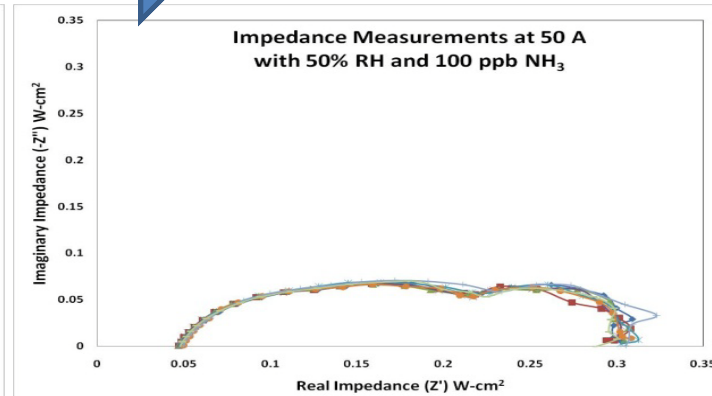
Fuel Cell Testing-Ammonia

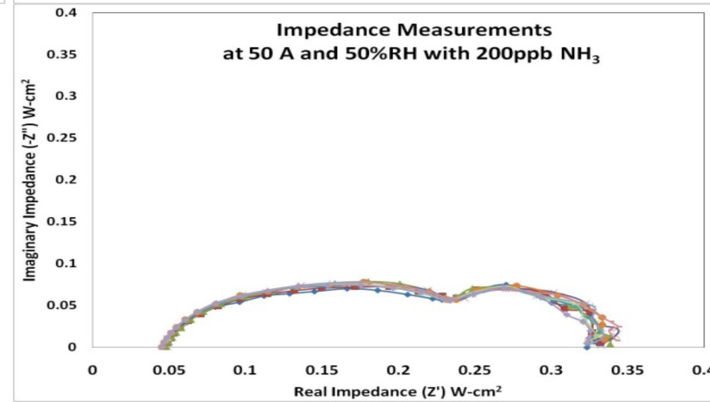
Impedance Spectroscopy

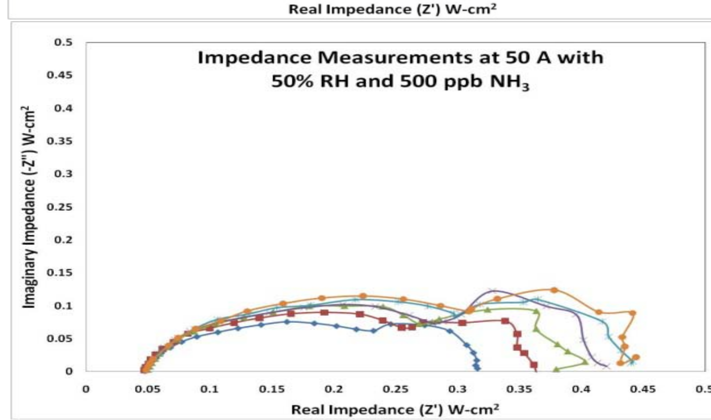
Experimental details: 80oC, H2/Air: 83/50% utilization, 25 psig
Impedance measured every 10h at 50A from 10kHz to 0.1 Hz,
(3% Amplitude Modulation)

Increasing RH









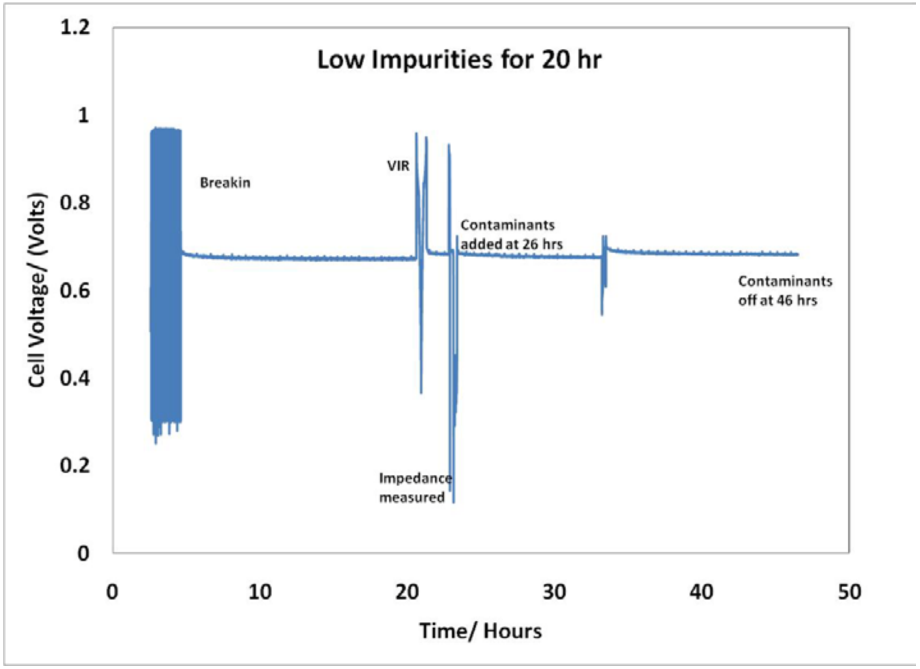
Increasing Ammonia Concentration

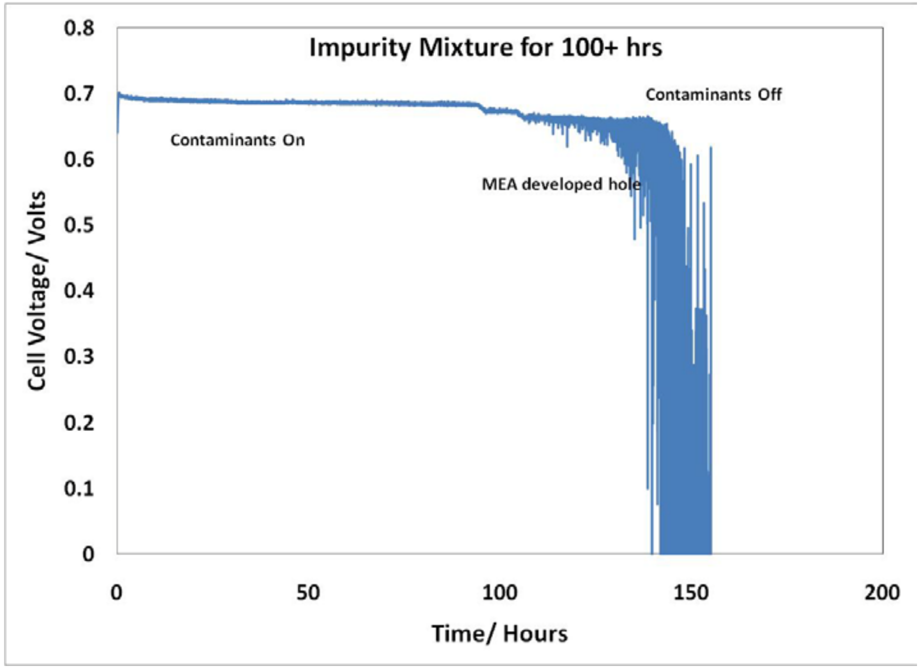
Changes CTR account for initial losses, local ionomer impacted may be reversible.
HFR increase indicative of NH_4^+ build-up in the membrane, typically irreversible under normal FC operation
MTR: unchanged with increasing ammonia

Ammonia reacts to form ammonium cations and can impact the electrode and membrane reducing protonic conductivity. However, an increase in local water may reduce its negative impact.

Fuel Cell Testing - Mixture(NH_3, CO, & H_2S)

Tests were carried out using identical contaminant levels. We varied the exposure.

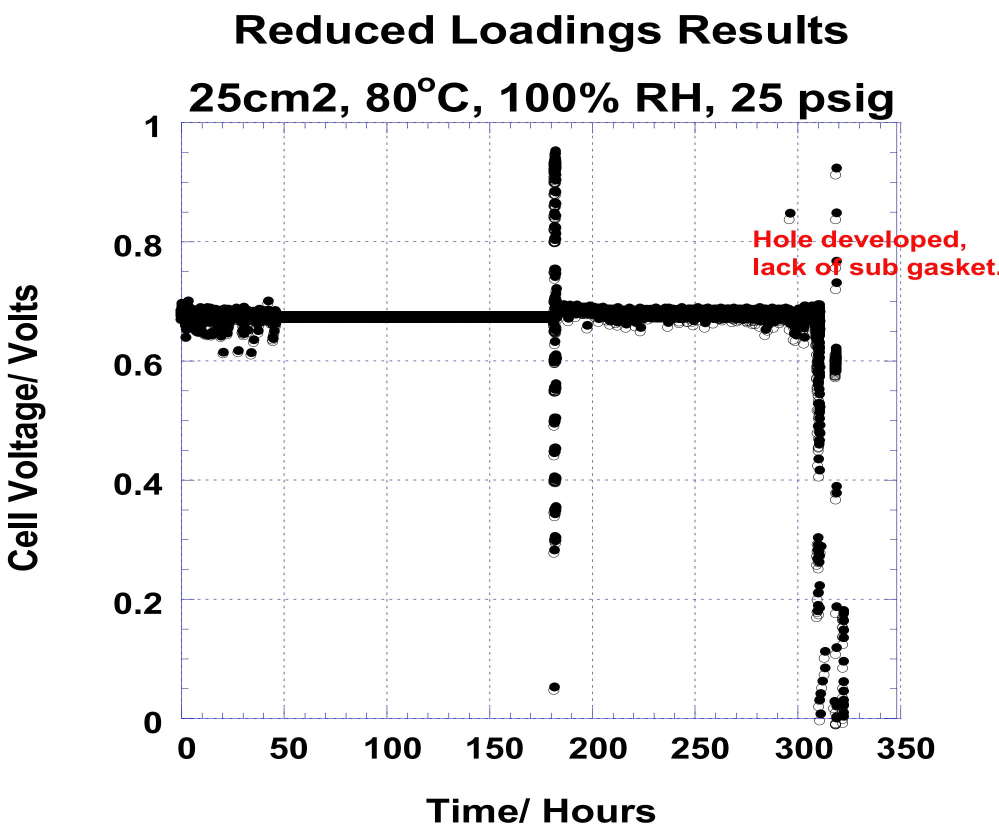


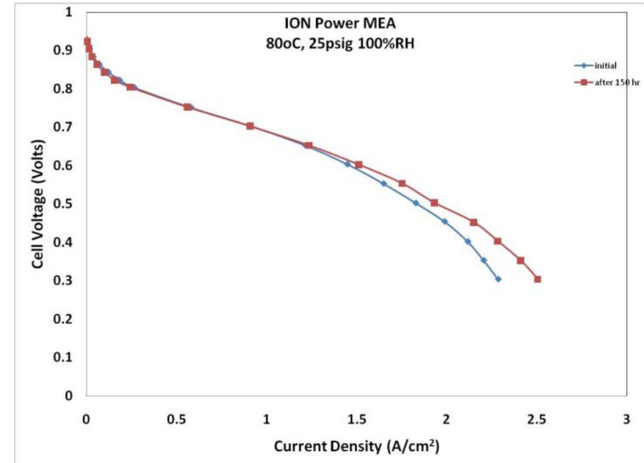


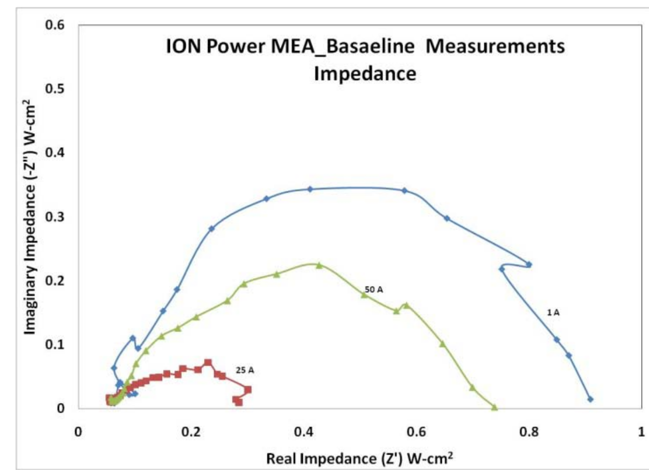
Results indicate tolerance to the critical constituents for short period. However, durability issues surface more readily with contaminant are present over longer times. This needs to be investigated to confirm whether or not this is due to the contaminants.

Fuel Cell Testing - Lower Loading

XRF indicated **0.35 mg Pt/cm² total loading**, (**A: <0.05 Pt mg/cm²**), ***Manufacturer agreed supply DOE '10 and '15 targeted loadings.***







Preliminary screening of MEAs show comparable performance to common MEAs, Beginning of test diagnostics are complete. MEA does not seem to have durability issues. In addition, **initial tests show tolerance at 200 ppb CO for 95 hrs**.

Incorporate New MEAs with DOE 2010 and 2015 targets

Remaining Tests for Fuel Specifications:

1. Testing critical constituents Fuel specification levels
2. Test at DOE targeted loadings: 0.2 mg Pt/cm^2 (DOE 2015 target)
3. Short term tests: typical vehicle operation (5-10 hours)
4. Start/stop Fuel Cell operation
5. Durability Test at cell level

Common MEA tests (A/C: 0.1/0.4 mg Pt/cm^2) have been conducted with:

- CO, NH_3, H_2S, and Mixtures

Results have been presented at multiple venues

Another MEA supplier has been identified to produce MEAs at DOE 2010 and 2015 targets (i.e. 0.3 and 0.2 mg Pt/cm^2)

- Sample MEA tested for possible durability concerns
- Initial experiments on CO conducted

Acknowledgements

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ISO TC197 Working Group 12 Members

FreedomCAR and Fuel Partnership Tech Teams

& Thank You - the AUDIENCE.