California Fuel Cell Partnership
DRIVING FOR THE FUTURE


Hydrogen Quality

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Acknowledgements

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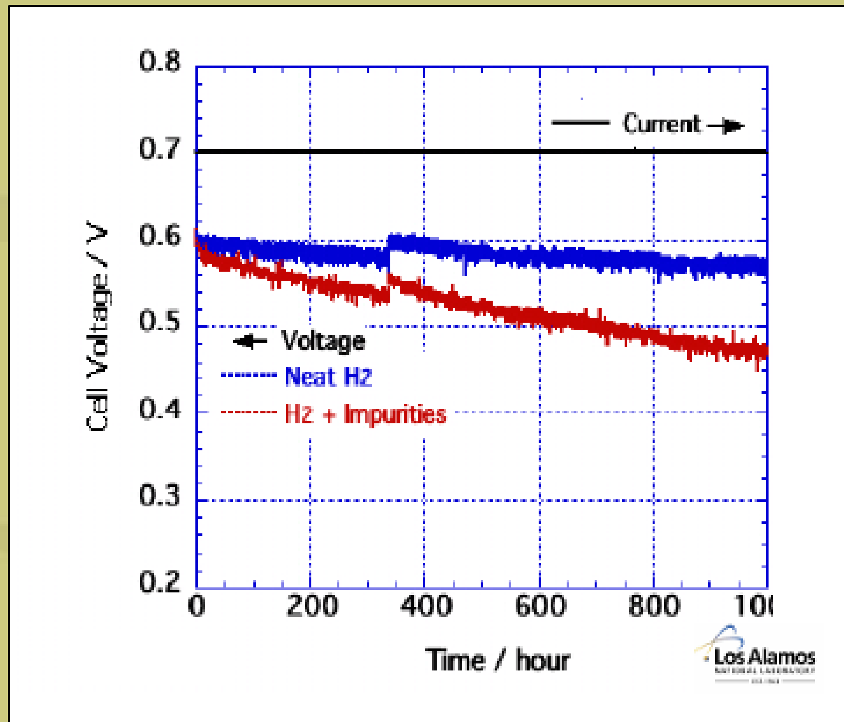
Defining hydrogen quality

The level of impurities in hydrogen fuel, specifically constituents and particulates.

Why is hydrogen quality important?

- Impurities negatively affect fuel cell performance
- PM can cause valve and seal malfunction
- Poor quality can cause inadequate vehicle operation



Hydrogen quality standards will protect the consumer!

The effect of standards

- Lax standards inhibit FCS cost and durability
  - DOE 2015 targets:
    - $30/kW for 60% peak-efficient, durable, direct hydrogen fuel cell power system for transportation
    - 5,000 hours fuel cell lifetime
- Stringent standards raise the price of fuel
  - DOE 2015 target: $2-3 gge for hydrogen

H2 quality standards development

- SAE and ISO set fuel quality standards
  - SAE TIR J2719 Hydrogen Quality Guideline for fuel cell vehicles
- ASTM sets testing standards
  - ASTM International Committee D03.14
- DMS enforces fuel delivery standards in California

Why is CaFCP involved?

- Real-world data of testing, sampling, and analysis
- Liaison between SDOs and CaFCP members
- Facilitates cooperation among industry segments and among SDOs
  - DMS activities

California's H2 quality regulation

- SB76 requires CA to adopt a standard by 1/1/08
  - Stakeholders believe its too soon for a standard
- Meetings at CaFCP to explore issue and options
  - Shortened the process
- DMS moved forward with an interim standard
  - Complies with the regulation
  - Avoided setting a permanent standard too soon

Proposed DMS interim standard

Specification	Value
Hydrogen Fuel Index (minimum, %) (1)	99.97
Total Gases (maximum, ppm v/v) (2)	300
Water (maximum, ppm v/v)	5
Total Hydrocarbons (maximum, ppm v/v) (3)	2
Oxygen (maximum, ppm v/v)	5
Helium (maximum, ppm v/v)	300
Nitrogen and Argon (maximum, ppm v/v)	100
Carbon dioxide (maximum, ppm v/v)	2
Carbon monoxide (maximum, ppm v/v)	0.2
Total Sulfur Compounds (maximum, ppm v/v)	0.004
Formaldehyde (maximum, ppm v/v)	0.01
Formic acid (maximum, ppm v/v)	0.2
Ammonia (maximum, ppm v/v)	0.1
Total Halogenated Compounds (maximum, ppm v/v)	0.05
Particulates Size (maximum, µm)	10
Particulate Concentration (maximum, µg/L @ NTP)	1

1. The hydrogen fuel index is the value obtained with the value of total gases (%) subtracted from 100%
2. Total Gases = Sum of all impurities listed on the table except particulates
3. Total Hydrocarbons may exceed 2 ppm v/v only due to the presence of methane, provided that the total gases do not exceed 300 ppm v/v.

- SAE and DMS coordination
  - SAE TIR J2719
- CaFCP member input on regulatory language

Testing to the standard

- ASTM - standardize test methods for sampling and analyzing hydrogen fuel quality
- How precise can you measure?
  - Can a standard call for an amount that is below what equipment can test?
- Test methods must be reproducible
- CaFCP provides real world data

HQSA

Hydrogen quality sampling adapter collects H2 samples from the station nozzle

HQSA results

Observations from aggregated results of 5 station tests:

1. Detectable limits change
2. Outliers from majority results
3. Large particulates

Note: all units in µmol/mol unless indicated otherwise

Constituent	SAE TIR J2719 Limits	Previous Smart Chemistry Detection Limits	Updated Smart Chemistry Detection Limits	Concentration (Outliers)
Water	5	1	1	< DL (2.2)
Total Hydrocarbons (C_1 Basis)				
Methane				< DL
Ethane, Ethene, Ethyne				< DL
Other Hydrocarbons				< DL (0.14)
Oxygen				< DL
Helium, Nitrogen, Argon	100			
Helium		10	10	< DL (78)
Nitrogen		5	5	< DL (762)[1]
Argon		0.8	0.8	< DL
Carbon Dioxide	1	0.4	0.4	< DL (1.2)
Carbon Monoxide	0.2	0.1	0.1	< DL
Total Sulfur	0.004			
Hydrogen Sulfide		0.001	0.0005	< DL
Carbonyl Sulfide		0.001	0.0005	< DL (0.0018 – 0.0046)
Methyl Mercaptan		0.001	0.0005	< DL
Carbon Disulfide		0.001	0.0005	< DL
Formaldehyde	0.01	0.004	0.002	< DL
Formic Acid	0.2	0.06	0.02	< DL
Ammonia	0.1	0.04	0.04	< DL
Total halogenates	0.05			
Chlorine		0.05	0.05	< DL
Hydrogen Chloride		10	0.05	< DL
Hydrogen Bromide		10	0.05	< DL
Organic Halides			0.02	< DL
Particulate Size	< 10µm		1µm	
Number of P… …ore than 1 cm				(1)[2]
Number of Particul… …mm and 1 cm				19
Number of Particu… …and 1000 µm				39
Number of Particulate with size within 10 µm and 100 µm				3[3]
Particulate Concentration	1µg/L	Balance	0.002…	0.0025 – 0.019 µg/L

[1] Underlined numbers indicate outli… …mmended limits.
[2] Underlined numbers in the "Part… …d the SAE recommended sizes.
[3] The three smallest particulates fo… …e found during sampling the smaller particu…

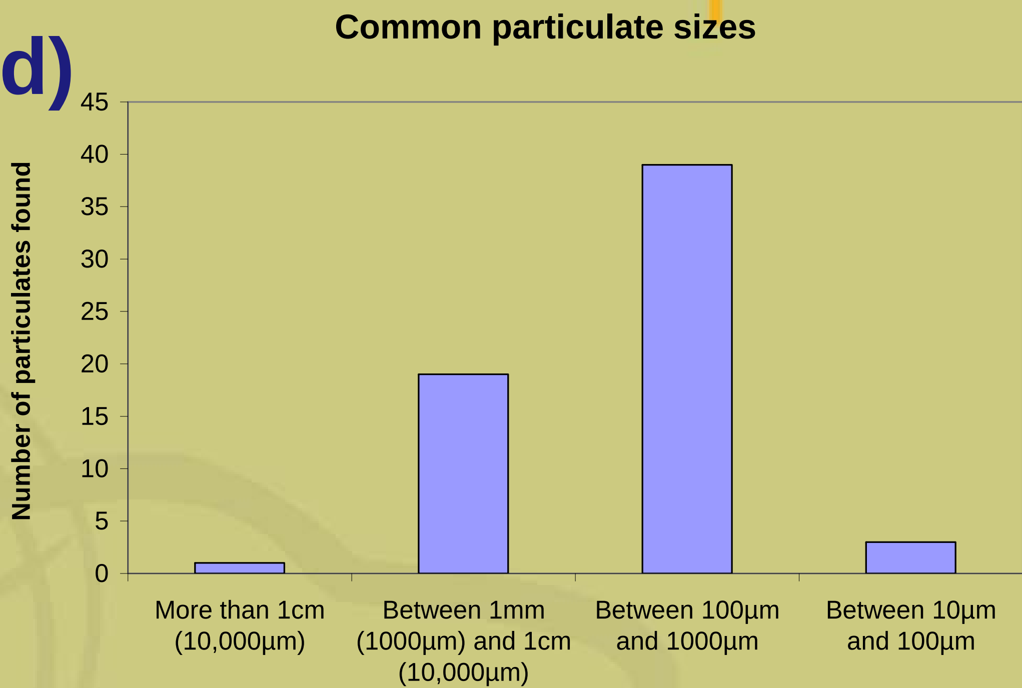
Nitrogen = 762 vs. 100 (SAE)

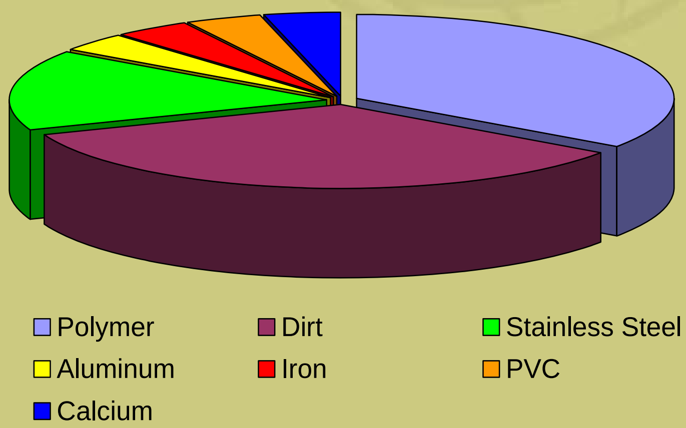
10 to 0.05

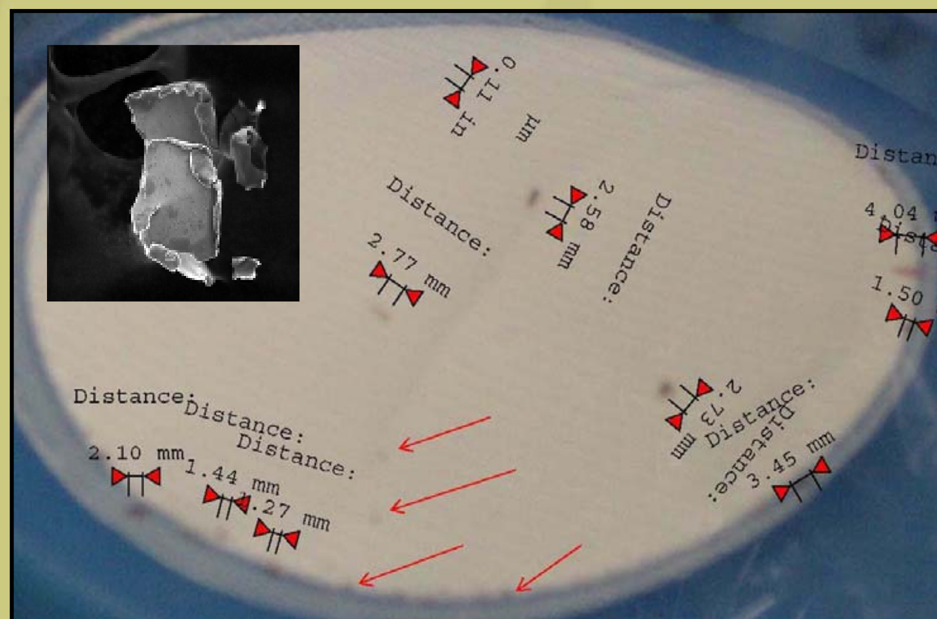
Particulates exceed SAE size

HQSA results (Cont'd)

- Particulates varied in size and composition
- Particulate sizes exceeded SAE limits







Test conclusions

- Samples came from five stations
  - Mix of liquid delivery, electrolysis and SMR
  - No conclusions related to production/delivery from tests
- Research will continue, especially in particulate sizes
- Real-world field testing will continue
  - More tests planned this year

Standards development continues

- Developing standards for fuel quality is necessary
- Developing standards isn’t fast and easy
- Providing real-world data is vital
- CaFCP will continue to play a role

California FUEL CELL PARTNERSHIP

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Collaboration is the key