Fuel Specification for fuel cells

EU workshop on Regulations, codes and standards for H₂/FC technologies
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ECN-Fuel Cell Technology
Outline

• Fuel Cell Applications and Fuels
• Fuel diversity and Fuel Cells
• Production of Fuels for Fuel Cells
  • Centralised
  • Decentralised
• Impurities for PEMFC
• Impurities in Fuel Processing
• Conclusions
Fuel Cell Applications and Fuels

- **Portable Power (1-200 W)**: Hydrogen, Methanol, Propane
- **Micro CHP (1-5 kW)**: Natural Gas, Propane
- **Stationary Power (< 250 kW)**: Natural Gas
- **City Transport (2-5 kW)**: Hydrogen, Gasoline
- **Transport (50-200 kW)**: Gasoline
- **Ships APU and propulsion (10-10000 kW)**: Marine oil, Kerosine
- **Airplane APU (100-500 kW)**: Kerosine
Fuel specifications and reformate/hydrogen production

Centralised production of Hydrogen
Natural Gas, LPG

Established tolerance levels
Aromatics
Organic Sulphur
Inorganic Sulphur

Decentralised production of hydrogen reformate
- Natural gas
- LPG
- Gasoline
- Diesel
- Kerosine
- Biofuels

Established tolerance levels
H₂S, CO, CO₂, NH₃, H₂S

Established tolerance levels
CO
CO₂
NH₃
H₂S
SO₂
eq
c

Fuel Cell
Stack

Fuel Processor

Hydrogen storage

Compressor

Fuel and air specification needed

Air

Hydrogen or air

Established tolerance levels

Natural gas
LPG
Gasoline
Diesel
Kerosine
Biofuels
Fuel diversity and fuel cells

- Natural Gas
- LPG
- Middle Distillates
- Liquid Bio-fuels
- Gas-to-Liquids
- Solar
- Wind
- Synthesis Gas
- PEMFC
- PAFC
- SOFC
- MCFC
- Hydrogen
- Methane
- Biomass
- Natural Gas
- LPG
- Middle Distillates
- Liquid Bio-fuels
- Gas-to-Liquids
- Solar
- Wind
- Synthesis Gas
- PEMFC
- PAFC
- SOFC
- MCFC
- Hydrogen
- Methane
- Biomass
Centralised Hydrogen production

- Desulphurizer
- Reforming
- Stack
- Heat recovery (Convection section)
- Heat recovery and cooling
- PSA System
- PSA purge
- Gas drum
- Process steam
- H.T. shift

99,999 % H₂
Decentralised Hydrogen production

NG LPG → Sulphur Removal → CPO ATR SR → HT shift → LT shift → PROX

fuel cell

exhaust

Combined Heat & Power (1-5 kW)
Influence of impurities

- PEMFC
- Reformer
  - Primary reformer (SR/ATR/CPO)
  - Shift (HT & LT)
  - Pref. Oxidation (Prox)
Influence of CO in reformate PEMFC

Mean cell potential [V] vs. Current density [A/cm²]

- H2
- 43%H2 / 41% N2 / 16%CO2
- ,, + 10 ppm CO
- ,, + 10 ppm CO + 1.5% air

Conditions:
- 70-75 °C
- 1 atm l=1.25/2

Source: ECN
Influence of H$_2$S in hydrogen for PEMFC

![Graph showing the effect of H$_2$S concentration on cell voltage over time. The graph compares the cell voltage for 2 ppm H$_2$S (red line) and 0.2 ppm H$_2$S (blue line). The cell voltage decreases over time, with the 2 ppm H$_2$S line showing a more pronounced decrease compared to the 0.2 ppm H$_2$S line. The source of the data is ECN.]
Influence of CO$_2$ in reformate PEMFC

Reverse watergas shift

CO$_2$ + H$_2$ $\leftrightarrow$ CO$_{g,ads}$ + H$_2$O

20% CO$_2$ is equivalent to 10 ppm CO

Reverse WGS is hindered on PtRu

Source: ECN
Influence of NH$_3$ concentration in reformate PEMFC

Stationary performance of a cell fed with a mixture of 75% H$_2$ / 25% N$_2$ and 5 ppm NH$_3$ in the interval from 210 hours to 475 hours. Current density is 500 mA/cm$^2$.

Source: ECN
Influence of NH$_3$ in cathode air PEMFC

Anode = cathode = 0.4 mg.cm$^{-2}$ Pt

10 ppm NH$_3$

Source: ECN
Influence of SO$_2$ in cathode air PEMFC

Source: ECN
Example Sulphur influence on CPO reforming (typical conditions)

Same trend is visible for Shift

Source: ECN
Impact on lack of fuel specifications for fuel cells; example: Sulphur

• DESIRE (WEU project).
  Initial fuel specification: NATO-F76 (0.2 wt.% S)
  R&D spent on sulphur removal: app. 200 kEuro
  By lack of success in S removal from F-76, City diesel (10 ppm S) is now used.

• Celina (EU project)
  Fuel specification: 3000 ppm (kerosene)
  R&D to be spent on fuel characterisation and sulphur removal: app. 250 kEuro.
Impact on lack of fuel specifications for fuel cells (2): example: Sulphur

Optimisation of centralised production of low sulphur fuels in refinery vs. decentralised S-removal (which needs a lot of R&D)
Fuel specifications/conclusions

• Should not only focus on hydrogen

• Should not only focus on fuel cell, also on reformer components

• Quick decisions on future fuel specifications can save a lot of R&D efforts and money. Especially for liquid fuels with S presence.

• Specifications need to be a compromise between impact on cost for fuel cell, costs for hydrogen production and costs for infrastructure.

• It makes no sense to have a fuel quality for the fuel cell which is much higher than the air quality.