Annual OTT Fuel Cells Program Review

Pacific Northwest National Laboratory, June 2000

DIRECT METHANOL FUEL CELLS

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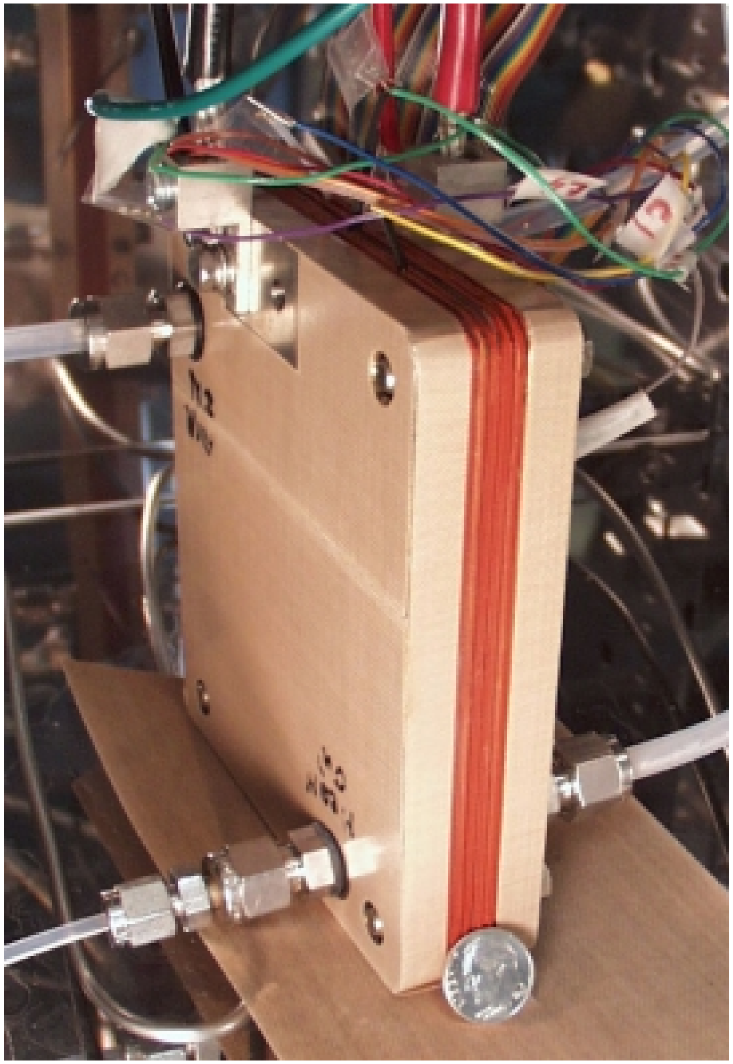
Direct Methanol Fuel Cells
Outline

- **From 5-cell to 30-cell DMFC stack.**
- **Further success in lowering catalyst loadings.**
- **Responding to the “practical methanol” challenge.**
- **Testing a DMFC MEA of lower crossover.**
- **Future plans.**

1999: LANL 5-Cell 45-cm^2 DMFC Stack



DMFCs for Potential Transportation Applications
Status by End of Last Year

- **A 5-cell LANL stack operated at 100°C with 2.8 atm air generated 1 kW per liter of active stack volume.**

- **At the design point of 0.50 V per cell, the 5-cell stack achieved a fuel utilization of 90%, which corresponds to an overall conversion efficiency of 37%.**

- **Catalyst loading was lowered to 5 g Pt per kW (in 5-cm^2 cell), as compared to about 2 g Pt per kW, estimated for today's on-board reforming system.**

Direct Methanol Fuel Cells

June '99: Reviewers' Comments

Relevance:

(1) Success here could lead to a much simpler fuel cell system.
(2) Highly relevant – could have major impact.
(3) It is a little distracting that Los Alamos seems to have become an advocate for DMFCs.

Industrial Collaborations: *Overall insufficient.*

Recommendations:

(1) Continue this work and (strongly) go for a 1 kW DMFC stack – this could be the Holy Grail of fuel cell work.
(2) Keep up effort on catalyst.
(3) Concentrate on crossover mechanism.
(4) Address the full DMFC system issues and performance, especially water balance.

Direct Methanol Fuel Cells
Industrial Collaborations

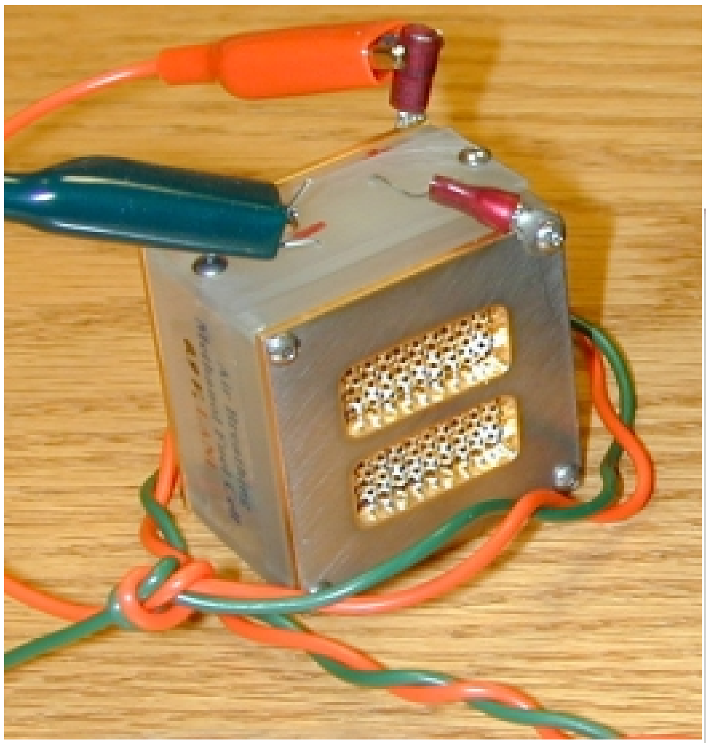
- **Joint project with Motorola announced January 19, 2000: DMFCs for consumer electronics applications.**

- **Starting discussions with two industries from automotive sector regarding possible collaboration on DMFCs at the 1 kW (and above) power level.**

- **Collaboration with Symyx Technologies on the development of new anode catalyst.**

DMFC Application: Portable Power

Motorola Labs, together with members from Motorola's Energy Systems Group have assigned a research team to Los Alamos to form a center of excellence that plans to drive this new technology into the marketplace.



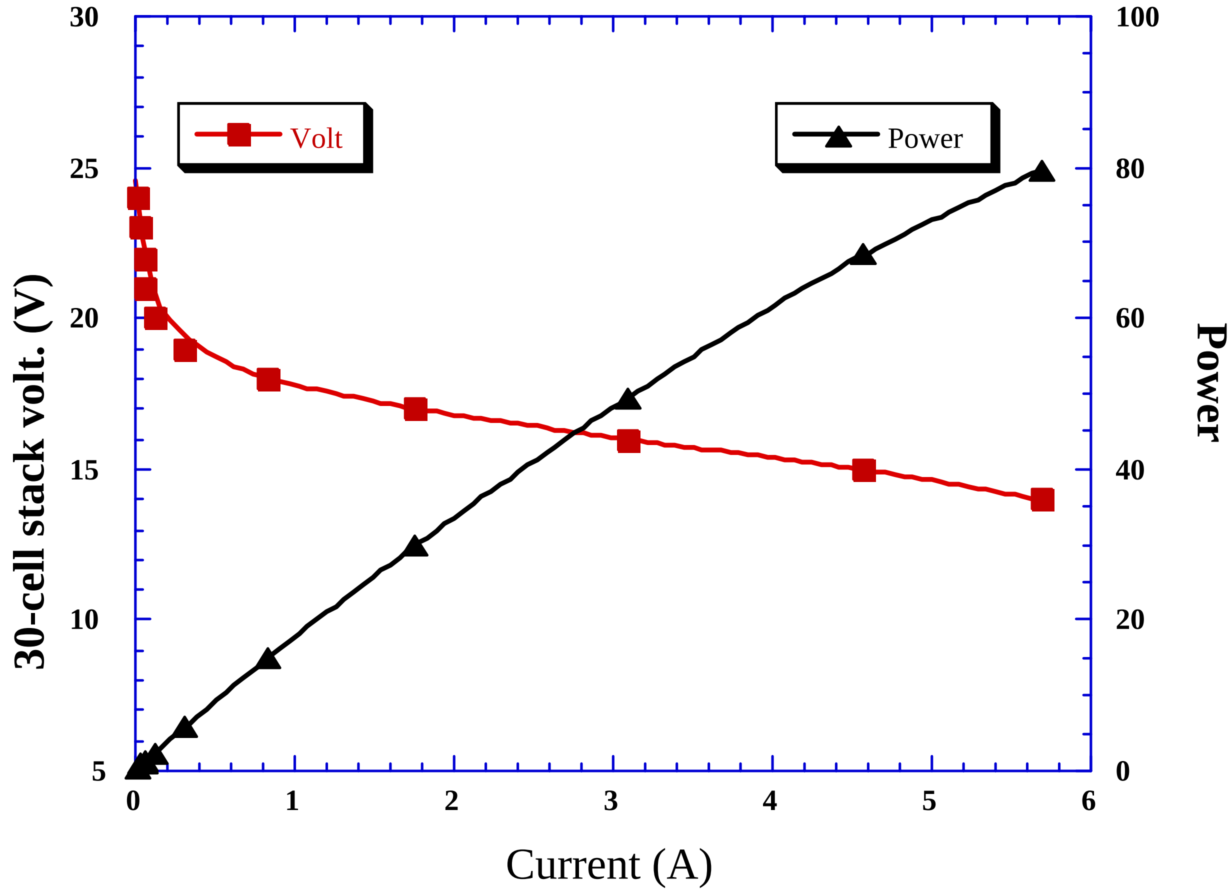
2000: LANL 30-Cell 45-cm^2 DMFC Stack

(1) 80W gross power near ambient conditions demonstrated for 50 W power system to be assembled by Ball Aerospace.

(2) 200 W gross power expected near 100°C.

New 30-Cell DMFC Stack

Performance at 60°C, 0.76 atm Air*

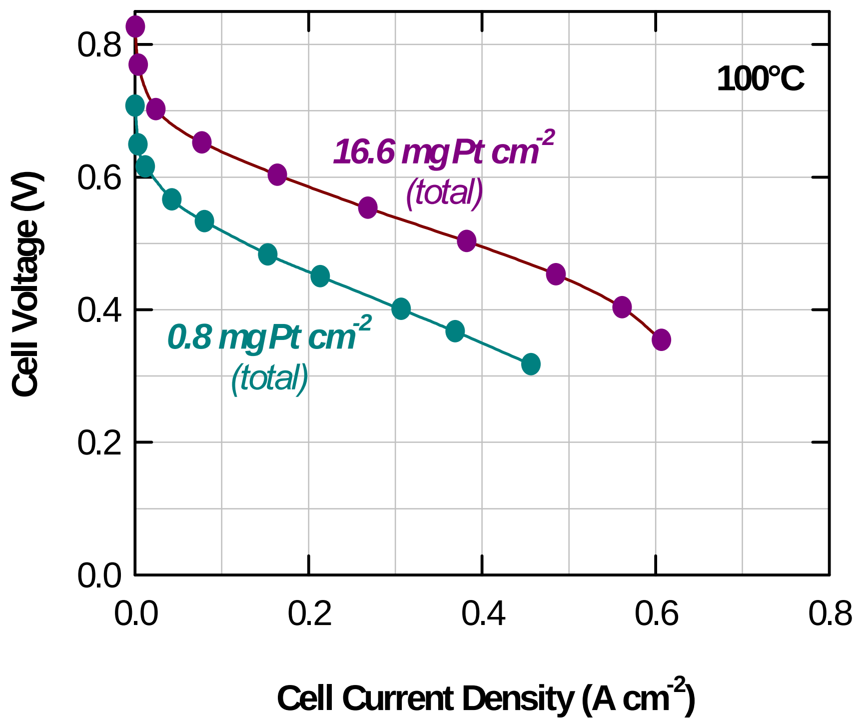


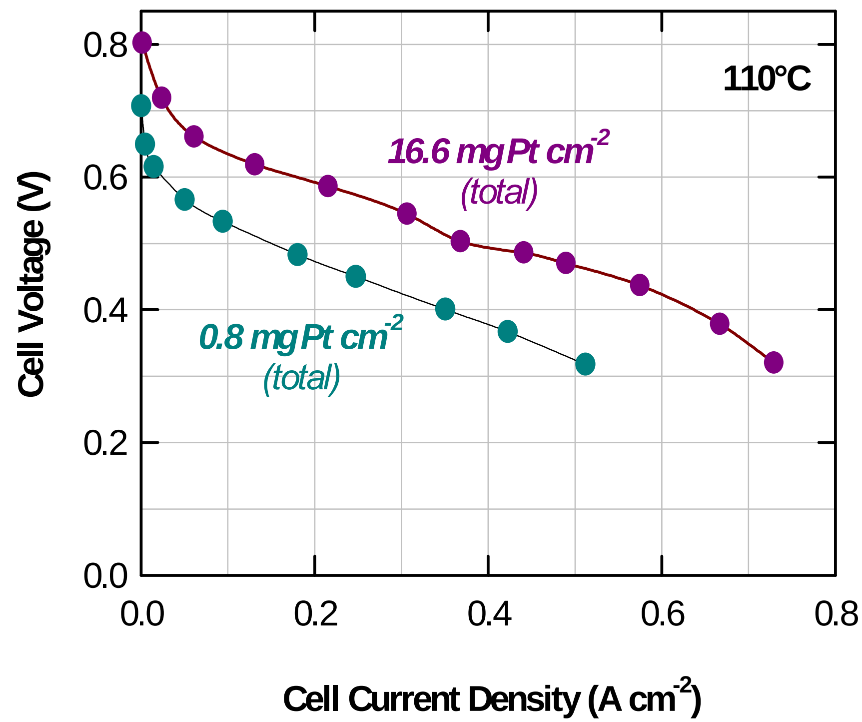
Portable power source applications

DMFC Stack
Fabrication & Testing Plans

- **Second version of the 30-cell stack delivered to Ball Aerospace for system integration (DARPA project on 50 W DMFC system).**
- **Equivalent 30-cell stack to be tested at elevated temperatures by Dec ’00. We expect peak power of 200 W near 100°C.**
- **We would like to pursue a 1 kW DMFC stack (budget permitting).**

DMFC Polarization Curves for Ultra-High & Low Pt Loadings at 100 & 110°C (45-cm² Cell)





MeOH: 1.0 M, 7 mL min^{-1}, exhaust pressurized at 20 psig.
Air: 5 stoich flow at 0.5 A cm^{-2}, 30 psig, humidified at 105-115°C.

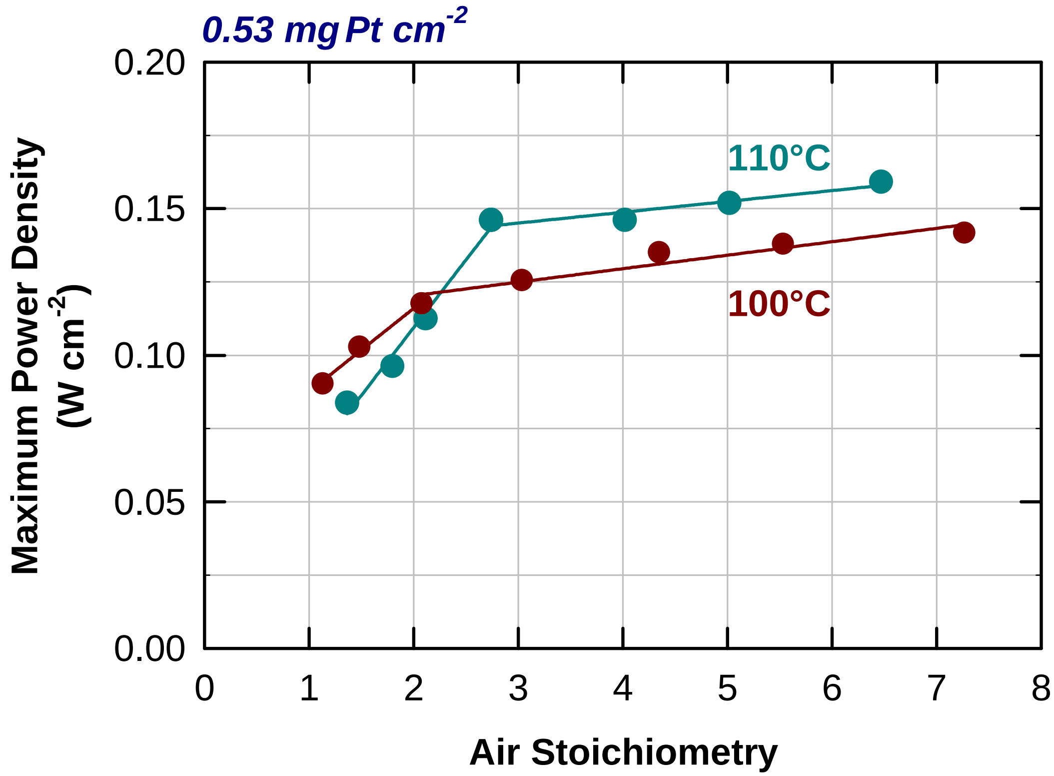
Trade-off Between Peak Power Density and Catalyst Requirement per kW with Lowering of Overall Pt Loading

MeOH: 1.0 M, 7 mL min^{-1}, exhaust pressurized at 20 psig.
Air: 3-6 stoich flow, 30 psig, humidified at 105°C
Cell: 100°C

Total Pt Loading ($mg\ cm^{-2}$)	g / kW*(peak)*	Peak Power ($W\ cm^{-2}$)
16.6	73.8	0.225
1.1	6.2	0.180
0.8	5.5	0.150
0.5	3.8	0.140
0.4	2.8	0.135
0.2	1.6	0.115

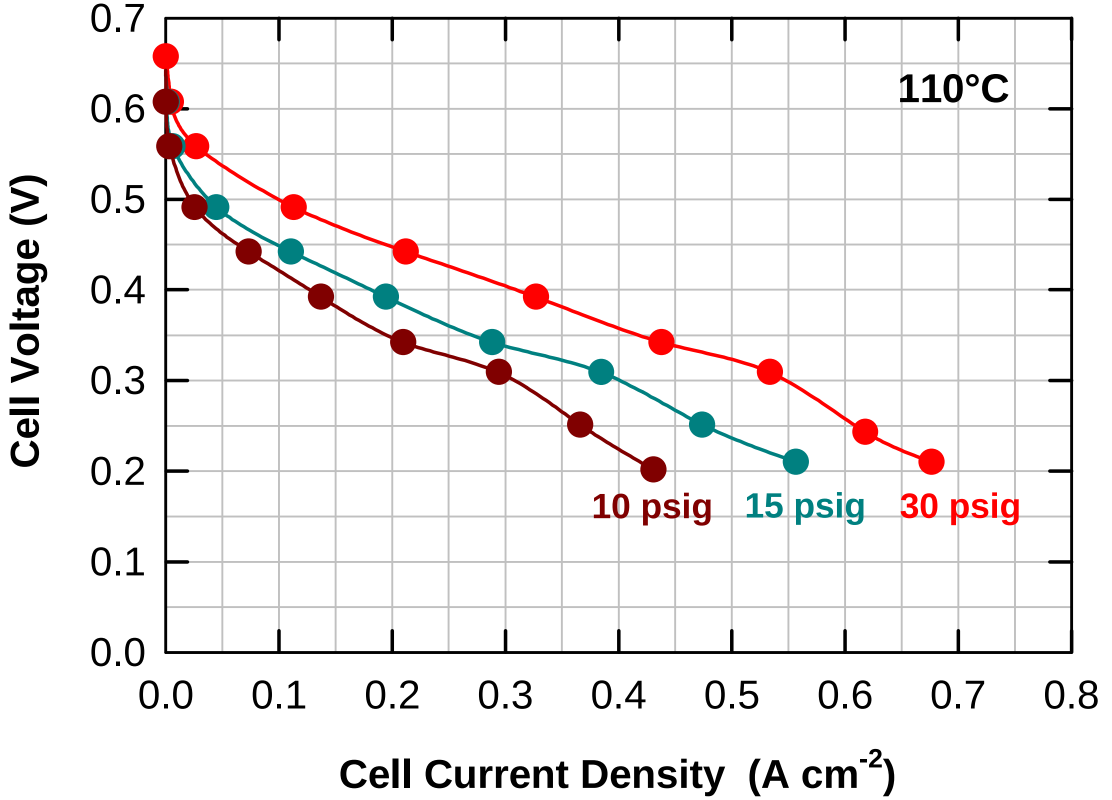
Milestone of 5 g Pt / kW achieved with 45 cm^2 cell at peak power of ~0.15 $W\ cm^{-2}$ (at 2 g Pt / kW, peak power still ~0.12 $W\ cm^{-2}$).

High Quality Air Cathodes Enable Good DMFC Performance at Air Stoich Flow Below 3, with Low Pt Loading (4 g/kW)



MeOH: 1.0 M, 7 mL min^{-1}, exhaust pressurized at 20 psig.
Air: 30 psig, humidified at 105-115°C.

Effect of Air Pressure on DMFC Performance at Low Catalyst Loading (0.53 mg Pt cm^{-2})



MeOH: 1.0 M, 7 mL min^{-1}, exhaust pressurized at 20 psig.
Air: 5 stoich flow at 0.5 A cm^{-2}, 30 psig, humidified at 115°C.

DMFCs of Good Performance and Significantly Lower Catalyst Loadings: FY-2000 Results & Conclusions

- ✓ **Milestone:**

  Demonstrate DMFC at 5g Pt/kW in 50 cm^2 cell.

  Result (100°C):

  5 gPt/kW *demonstrated at 0.15 W(peak)* cm^{-2},
  2 gPt/kW *demonstrated at 0.12 W(peak)* cm^{-2}

- ✓ **Carbon-supported Pt-Ru catalysts seem appropriate for maximizing power at lower anode loading.**

- ✓ **Good performance with 5 gPt/kW achievable at 20 psig air, less than 3 stoich flow of air.**

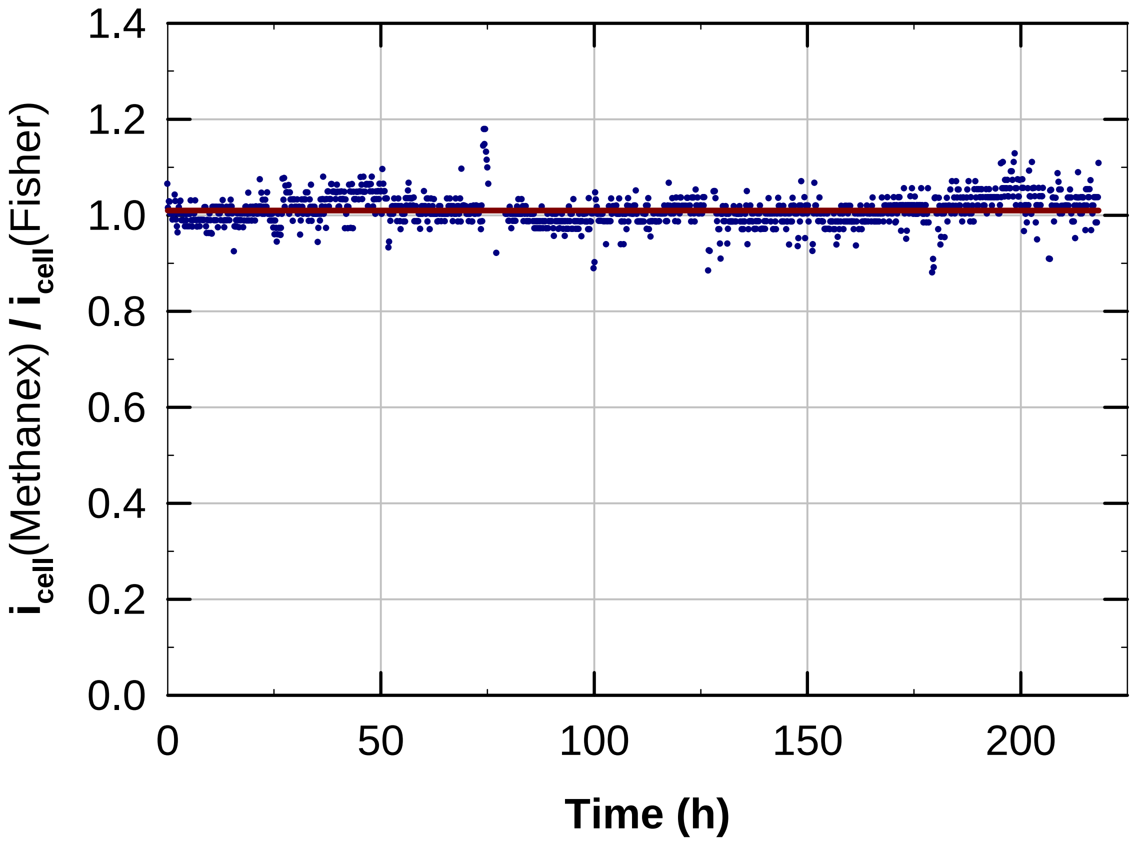
DMFC Test with Commercial & Analytical Grade Methanol

Commercial Grade Methanol
Methanex Corporation
Medicine Hat, Alberta, Canada

Analytical Grade Methanol
Fisher Scientific

DMFC Test with Commercial & Analytical Grade Methanol

200-Hour Life test (100°C, 0.50 V)



i_{cell}(Methanex) **/** i_{cell}(Fisher) **= 1.01 ± 0.03**

DMFC Test with Commercial & Analytical Grade Methanol
Summary

- **Performance of two DMFCs with:**

  (1) Methanex Commercial Grade ("out of the gate") MeOH
  (2) Fisher Analytical Grade MeOH

  have been perfectly identical.

- **It seems very likely that contaminants argued before in "practical methanol", if indeed present, originate from handling & distribution.**

- **DFMCs do not seem to require special "fuel cell grade" methanol.**

Alternative DMFC Membrane *(Provided by Giner)*

Test Data at 60°C

Test	Giner MEA (# 588-39-03)	LANL MEA (Nafion 117)
Cell Performance at 0.50 V, *A cm*$^{-2}$	**0.048**	**0.157**
Anode Performance at 0.35 V, *A cm*$^{-2}$	**0.100***	**0.274***
High-Frequency Resistance, *Ω cm*^{2}	**0.22 - 0.24**	**0.20 - 0.22**
MeOH Crossover at OCV, *A cm*$^{-2}$	**0.08**	**0.11**

***** *iR-corrected value*

Alternative DMFC Membrane
Summary

- **Giner membrane exhibits lower crossover by 25-30% *vs.* Nafion 117, at the same membrane resistance. This by itself can be considered of value.**

- **Lower performance of Giner MEA may be caused by:**
  - ***Poor anode catalyst and/or lower catalyst loading***
  - ***Interfacial catalyst/membrane issues***

- **Giner membrane is, unfortunately, mechanically fragile, particularly when dry.**

DMFC Task Milestones

- **Apr '00** **Demonstrate 5 g Pt / kW in 50 cm^2.**
- **Aug '00** **Demonstrate 5 g Pt / kW in short (5-cell) stack.**
- **Aug '00** **Complete fabrication of 0.2 kW, 30-cell stack.***
- **Dec '00** **Test and report on performance and performance stability of 0.2 kW stack at 100°C.**
- **Mar '01** **Experiment and document air & water management issues for 0.2 kW DMFC stack.**
- **Sep '01** **Advance to 1-2 kW stack.**

Size downgraded due to budget limitation.