AN UPDATE OF DIRECT METHANOL FUEL CELL TECHNOLOGY

JPL

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WINDSOR WORKSHOP
ON TRANSPORTATION FUELS
Windsor Ontario, Canada
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DIRECT METHANOL, LIQUID-FEED FUEL CELL / PEM SCHEMATIC DIAGRAM

D. C. MOTOR

- ELECTRODE

POLYMER MEMBRANE (PEM)

+ ELECTRODE

CO₂
Methanol /water

FUEL
3% Methanol / Water

OXIDANT
Air (O₂)

H₂O, N₂, O₂

H₂O

MeOH

H⁺

H⁺

- ELECTRODE
DIRECT METHANOL, LIQUID-FEED FUEL CELL REACTIONS

Anode \[ \text{CH}_3\text{OH} + \text{H}_2\text{O} = \text{CO}_2 + 6\text{H}^+ + 6\text{e}^- \]

Cathode \[ 6\text{H}^+ + \frac{3}{2}\text{O}_2 + 6\text{e}^- = 3\text{H}_2\text{O} \]

Net Reax \[ \text{CH}_3\text{OH} + \frac{3}{2}\text{O}_2 = \text{CO}_2 + 2\text{H}_2\text{O} \]

1 LITER OF CH₃OH CAN PRODUCE ~ 5000 Wh
34% (1700 Wh/l) ACHIEVED THUS FAR
Step 1: Dissociative Chemisorption

CH₃OH + H₂O →s
Pt Ru

Step 2: Surface combination and electrochemical reaction

H⁺ H⁺ H⁺
Pt Ru

H⁺ H⁺ H⁺
Pt Ru

CO₂

electrons
## PROPERTIES OF OXYGENATED FUELS

<table>
<thead>
<tr>
<th>FUEL</th>
<th>B. P. (°C)</th>
<th>E°</th>
<th>Ah/g</th>
<th>Wh/kG</th>
<th>Density</th>
<th>Wh/l</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCHO</td>
<td>-21</td>
<td>1.350</td>
<td>3.57</td>
<td>4820</td>
<td>.82</td>
<td>3952</td>
</tr>
<tr>
<td>CH₃OH</td>
<td>65</td>
<td>1.21</td>
<td>5.03</td>
<td>6086</td>
<td>.82</td>
<td>4976</td>
</tr>
<tr>
<td>C₂H₅OH</td>
<td>78.5</td>
<td>1.143</td>
<td>6.99</td>
<td>7989</td>
<td>.79</td>
<td>6311</td>
</tr>
<tr>
<td>(CH₃O)₂CH₂</td>
<td>47</td>
<td>1.21*</td>
<td>5.64</td>
<td>6826</td>
<td>.89</td>
<td>6075</td>
</tr>
<tr>
<td>(CH₃O)₃CH</td>
<td>100</td>
<td>1.21'</td>
<td>5.06</td>
<td>6110</td>
<td>.97</td>
<td>5927</td>
</tr>
<tr>
<td>H₂ (Lq)</td>
<td>-259</td>
<td>1.23</td>
<td>26.8</td>
<td>32964</td>
<td>.07</td>
<td>2307</td>
</tr>
</tbody>
</table>

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DIESEL (KEROSENE)  

<p>| | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>10000</td>
<td>.82</td>
<td>8200</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

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ELECTRIC POWER SECTION
ADVANCES IN DMLFFC/PEM PERFORMANCE

300 mA/cm²

A R AT 20 PSIG, 90°C
FUEL: 3% METHANOL
4” x 6” ELECTRODE AREA

CELL VOLTAGE, Volt

0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0

CURRENT (Amps)

6 32 48 64 96 2 128


Device Research and Applications Section
PERFORMANCE ON AIR AND OXYGEN

0.56 V attained with oxygen; 0.50 V attained with air

Device Research and Applications Section
Scales linearly as the single cell; works as per design
POWER DENSITY OF THE DMLFFC/PEM

JPL data at 90°C, C, 2.5 atm, 5L/mI
2" X 2" Electrode

POWER DENSITY, mW/cm²

CURRENT (Amps) (based on 160 cm² Electrode)

~300mW/cm² with oxygen -200 mW/cm² with air

DEVICE RESEARCH AND APPLICATIONS SECTION
PROJECTED ADVANCES IN STACK PERFORMANCE
WITH AIR AT 300 mA/cm² & 90°C

State-of Art
1996

- 0.50 volts
- 42% Voltage Efficient
- 80% Fuel Efficient
- 34% Overall

Reduce X-Over
1997

- 0.55 volts
- 46% Voltage Efficient
- 90% Fuel Efficient
- 41% Overall

Reduce X-Over
& Improve Membrane Electrode Assembly
1998

- 0.60 Volts
- 50% Voltage Efficient
- 95% Fuel Efficient
- 47% Overall

WITH LOW CROSSOVER.

HIGHER MeOH CONCENTRATION IS POSSIBLE,

HIGHER CURRENT PROJECTED

DEVICE RESEARCH AND APPLICATIONS SECTION
<table>
<thead>
<tr>
<th>Watts per Liter W/l</th>
<th>344</th>
</tr>
</thead>
<tbody>
<tr>
<td>Watts per Kilogram W/kg</td>
<td>365</td>
</tr>
<tr>
<td>System Output Power (Given), kW</td>
<td>5</td>
</tr>
<tr>
<td>System Output Voltage (Given), V</td>
<td>50</td>
</tr>
<tr>
<td>No. of Cells in Electric Series</td>
<td>91</td>
</tr>
<tr>
<td>DH Voltage for Methanol / O₂</td>
<td>1.25</td>
</tr>
<tr>
<td>Required Cell Performance: Minimum Current Density, mA/cm²</td>
<td>300</td>
</tr>
<tr>
<td>Required Cell Performance: Minimum Single Cell Voltage, VDC</td>
<td>0.55</td>
</tr>
<tr>
<td>Single Cell Active Area, cm² (~ 18cm x 18cm)</td>
<td>316</td>
</tr>
<tr>
<td>System Weight, kg</td>
<td>14.7</td>
</tr>
<tr>
<td>System Volume, l</td>
<td>14.5</td>
</tr>
<tr>
<td>Length of Stack, cm/in</td>
<td>38 /15</td>
</tr>
<tr>
<td>Height of Stack, cm/in</td>
<td>19/7.5</td>
</tr>
<tr>
<td>Width of Stack, cm/in</td>
<td>19/7.5</td>
</tr>
</tbody>
</table>
SIMPPLICITY OF SYSTEM
SIMPPLICITY OF THERMAL AND WATER MANAGEMENT
C₀₂ AND H₂O ARE THE ONLY PRODUCTS
TWO-PHASE ALLOWS SIMPLE C₀₂ REMOVAL
NO CORROSIVE ELECTROLYTES OR SHUNT CURRENTS
AMENABLE TO SCALE-UP
OPERATION AT AT TEMPERATURES TO 95°C
START-UP AT 20°C
APPLICATIONS FOR THE DIRECT METHANOL, LIQUID-FEED FUEL CELL

BATTERY REPLACEMENT
TRANSPORTATION
LIGHT DUTY VEHICLES
EMERGENCY POWER
CONSUMER TOOLS
MARINE APPLICATIONS
COMMUNICATIONS
MOBILE POWER
DIRECT METHANOL, LIQUID-FEED FUEL CELL CONCEPT

- Uses 3% liquid methanol/water as the fuel
  - Air \( (O_2) \) as the oxidant

- Fuel mixture enters anode chamber
  - Produces protons \((H^+)\) and \(CO_2\)

- The polymer electrolyte membrane (PEM) separates the two electrodes
  - Provides the path for the \(H^+\) to transfer from the anode to cathode

- \(O_2\) flows into the cathode chamber
  - Reacts with \(H^+\) to produce water
DIRECT METHANOL, LIQUID-FEED FUEL CELL CONCLUSIONS

- DIRECT METHANOL, LIQUID-FEED FUEL CELLS HAVE A BROAD RANGE OF APPLICATIONS FROM THE LOW WATTS TO MULTI-KILOWATT.
- THE TECHNOLOGY DEVELOPMENT EFFORT IS PRESENTLY SUPPORTED BY GOVERNMENT, PRIVATE INDUSTRY, AND RESEARCH INSTIUTES
- COST SHARING BY INDUSTRY HAS ENABLED THE TECHNOLOGY TO MOVE FORWARD FROM THE LABORATORY
- THE JPL DMLFFC HAS THE HIGHEST PERFORMANCE AND PRESENT TECHNOLOGICAL ADVANTAGE WORLDWIDE
- SUPPORT NEEDED TO DEMONSTRATE STACK AND SYSTEM OPERATION TO MOVE THE TECHNOLOGY INTO COMMERCIALIZATION
ACKNOWLEDGEMENT

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