DIRECT METHANOL, LIQUID-FEED FUEL CELL PROGRESS AND PROSPECTS

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COMPARISON OF DIRECT AND INDIRECT METHANOL FUEL CELL OPERATION

INDIRECT METHANOL FUEL CELL SYSTEM

MEOH → MIXER → VAPORIZER → REFORMER → SHIFT CONVERTER → PROX → FUEL CELL → AIR

WATER CONDENSER

DIRECT METHANOL FUEL CELL SYSTEM

MEOH → FUEL CELL → AIR

WATER CONDENSER

DIRECT OXIDATION

1. REDUCES COMPLEXITY
2. REDUCES WEIGHT BY 25%-50%
3. IMPROVES RELIABILITY
4. REDUCES COST

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DIRECT METHANOL FUEL CELL
SYSTEM ADVANTAGES

ABSENCE OF POLLUTANTS
- \( \text{H}_2\text{O} \) AND \( \text{CO}_2 \) ARE THE ONLY PRODUCTS

COMPARSED TO \( \text{H}_2/\text{O}_2 \) FUEL CELLS DIRECT REACTION OF METHANOL SIMPLIFIES FUEL SYSTEM
- ELIMINATES HIGH PRESSURE HYDROGEN STORAGE
- ELIMINATES REFORMER TO CONVERT METHANOL TO \( \text{H}_2 \)
- NO WARMUP PROBLEMS AND SLUGGISH RESPONSE
- ELIMINATES HYDRIDE STORAGE

LIQUID FEED OF METHANOL
- REDUCES STACK COMPLEXITY (E.G. COOLING PLATES)
- CONVENIENT FUEL DELIVERY AND STORAGE
- LIQUID FUEL MIX PREVENTS SEPARATOR DRYOUT

OPERATION POSSIBLE AT ROOM TEMPERATURE
DIRECT METHANOL FUEL CELL SCHEMATIC

CO₂
Unused Methanol / Water

FUEL
3.0% Methanol / Water

ANODE - ELECTRODE

CATHODE - ELECTRODE

PROTON EXCHANGE MEMBRANE (PEM)

H₂O, AIR
(Unused O₂)

OXIDANT
AIR / O₂

LOAD

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

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

1 LITER OF CH$_3$OH CAN PRODUCE ~ 5.0 KWh
34% (1.7 KWh) ACHIEVED THUS FAR
PROJECTIONS FOR 1.2 KW DMFC STACK

3% MeOH in H₂O → PEM → Air

< 3% MeOH in H₂O

INTERNALLY MANIFOLDED
LOW PRESSURE
~6 CELLS / INCH
COMPOSITE MOLDED BIPLATES

1.2 KW @ 60°C, 2.4 KW @ 90°C
VOLTAGE ~16v
CELLS ~35
DIMENSIONS 27CM X 27CM X 14CM
PERFORMANCE IMPROVEMENT
FUEL: 3%(l m) ME OH, 90°C, AIR AT 20 PSIG, 4” x 6” ELECTRODE AREA

ADVANCES DUE TO
IMPROVEMENTS IN CATALYST COMPOSITION
IMPROVEMENTS IN ELECTRODE STRUCTURE
IMPROVEMENTS TO CATALYST / ELECTRODE /MEMBRANE INTERFACE
IMPROVEMENTS IN PROCESSING CATALYST

CELL VOLTAGE, Volt

CURRENT (Amps) (based on 160 cm² Electrode)
• Good Transient Response in the 0-500 ms range.
SUMMARY OF ADVANCES

- Demonstrated Power Densities of 230 mw/cm² (100 Amps on 4” x 6” electrode area)
- Demonstrated system operation at 50W level
- Developed an Demo’d Low Concentration MeOH Sensor
- Demonstrated Excellent Load Following
- Demonstrated Stable Catalyst Performance
  >400 Hours of Intermittent Operation
- New Methods for Layering Catalysts
  Reduces catalyst and cost
- New Proton Exchange Membrane
  Increased Efficiency to >45% and Reduced Cost
- Developed Model for Complete 150W System
  DARPA 150W System Demonstration 9/99
DIRECT METHANOL FUEL CELL SYSTEM CONCEPT

1. Methanol Tank
2. CO₂ Out
3. Vapor & Air Out
4. MeOH / H₂O
5. Condenser / Radiator
6. Fuel Cell Stack
7. Pump
8. Air Pressure
9. LOAD
10. H₂O Drain

3% MeOH → MeOH Sensor
TRANSPORTATION APPLICATIONS FOR THE
JPL DIRECT METHANOL FUEL CELL

Methanol + Air → Water → CO₂ → POLLUTION-FREE POWER

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APPLICATIONS FOR THE DIRECT METHANOL, LIQUID-FEED FUEL CELL

NEAR TERM
SAIL / POWER BOATS
EMERGENCY POWER
GOLF CARTS
PEOPLE MOVERS
AIRPORT VEHICLES
FACTORY TRUCKS
LAWN MOWERS

DIRECT METHANOL FUEL CELL VEHICLES
ARDEC HYBRID METHANOL SYSTEM
DARPA 150 WATT FUEL CELL SYSTEM

CHARACTERISTICS
- POWER: 150 W
- CAPACITY: 5000 WH
- VOLTAGE: 24V
- CURRENT: 6.25A
- MASS (W FUEL): 12 KG
- VOL.: 30 LITERS
- OP. TEMP.: 15-42°C
- START-UP: < 1 MIN.
DIRECT METHANOL 2.3 KW FUEL CELL SYSTEM
IN A LIGHT DUTY VEHICLE APPLICATION

PEOPLE-MOVER
LOAD CAPACITY 1600 LBS
BED VOLUME 253 LITERS
SYS. VOL. 80 LITERS
MASS 118 KG
MEOH TANK 10LITERS
ENERGY 12.3 KWH
CONT. OPER. 10 HRS
Projected Advances in Performance with Air at 300 mA/cm² & 90°C

METHANOL THEORETICAL ENERGY = 5kWh / LITER

1998 State-of-Art
- 0.50 Volts
- 42% Voltage Efficient
- 80% Fuel Efficient
- 34% Overall
  (1.7 kWh / L)

2000 Reduce X-Over with New Membrane
- 0.55 Volts
- 46% Voltage Efficient
- 90% Fuel Efficient
- 41% Overall
  (2 kWh / L)

2002 Reduce X-Over & Improve MEA
- 0.60 Volts
- 50% Voltage Efficient
- 95% Fuel Efficient
- 48% Overall
  (2.25 kWh / L)

With Lower Crossover, Can Use Higher MeOH Concentration

→ Higher Current Projected
METHANOL CROSSOVER AND ITS IMPLICATIONS

Implications:

Parasitic fuel loss; 20%
Lower cell voltage; by 0.1V
Increased air demand
Reduction in efficiency
New membranes have about 10% of the crossover observed with Nafion 117, and ionic conductivity similar to Nafion11100.
DIRECT METHANOL FUEL CELL
CHALLENGES AND RESOLUTIONS

• Reduce Methanol Crossover to Increase Efficiency
  – Solution - USC Membrane Cuts Crossover From 20-5%
  – Efficiency Increased from 34 to 45%

• Water Accumulation And Removal
  – Solution - New Flow Fields & Materials Solve Problem

• Catalyst Preparation Is Time Consuming
  – Solution - Engineering / Manufacturing Scale-Up Will Reduce Process Time

• Manufacturer Needed to Initiate Pilot Operation
  – Several Have shown Interest
  – Exclusive License Exists
A FINAL THOUGHT FOR YOUR CONSIDERATION

THE TECHNOLOGY IS READY

THE APPLICATIONS EXIST

THE ENVIRONMENT AWAITS

THE CHALLENGE IS FOR INDUSTRY TO MOVE IT INTO COMMERCIALIZATION
SUMMARY

• METHANOL FUEL CELLS HAVE APPLICATION OVER A WIDE POWER RANGE FROM LOW WATTS TO KILOWATTS

• METHANOL IS A CONVENIENT FUEL THAT IS EASY TO HANDLE AND STORE

• THE DIRECT METHANOL FUEL CELL IS LESS COMPLICATED, EASIER TO OPERATE, AND MORE COMPACT THAN THE COMPETING TECHNOLOGY

• MAJOR ADVANCES IN MEA TECHNOLOGY HAVE RESULTED IN SIGNIFICANT PERFORMANCE IMPROVEMENT

• LOW CROSSOVER MEMBRANE PROMISES FURTHER ADVANCES IN PERFORMANCE AND EFFICIENCY