DEVELOPMENT OF A 300W DIRECT METHANOL FUEL CELL BASED POWER SOURCE

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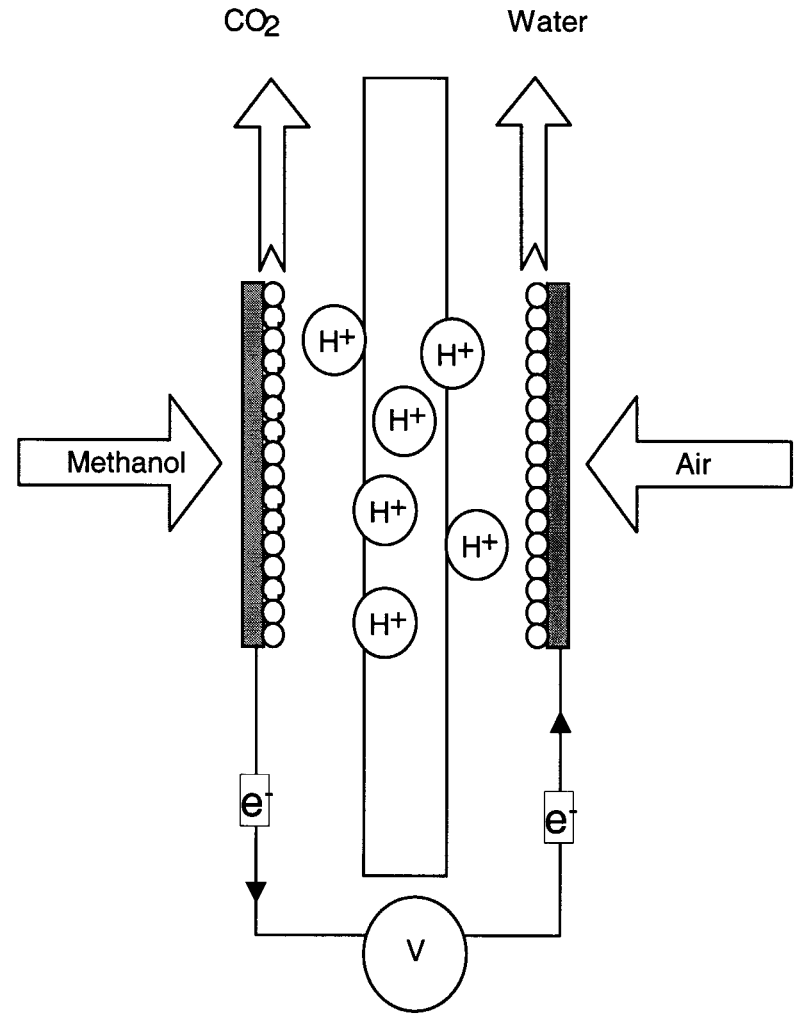
The Direct Methanol Fuel Cell

Direct Methanol Fuel Cell Reaction:

Anode: $CH_3OH + H_2O \rightarrow 6H^+ + 6e^- + CO_2$

Cathode: $3/2O_2 + 6H^+ + 6e^- \rightarrow 3H_2O$

Cell: $CH_3OH + 3/2O_2 \rightarrow CO_2 + 2H_2O$



DMFC Advantages

- Safety of handling a liquid fuel versus compressed gas fuel tank (i.e. Hydrogen)
- Low methanol concentration (<3%) in the "working" fuel loop

Objective, Background and Requirements

Objective

- Develop direct methanol fuel cell technology and demonstrate a 300 W prototype power source.

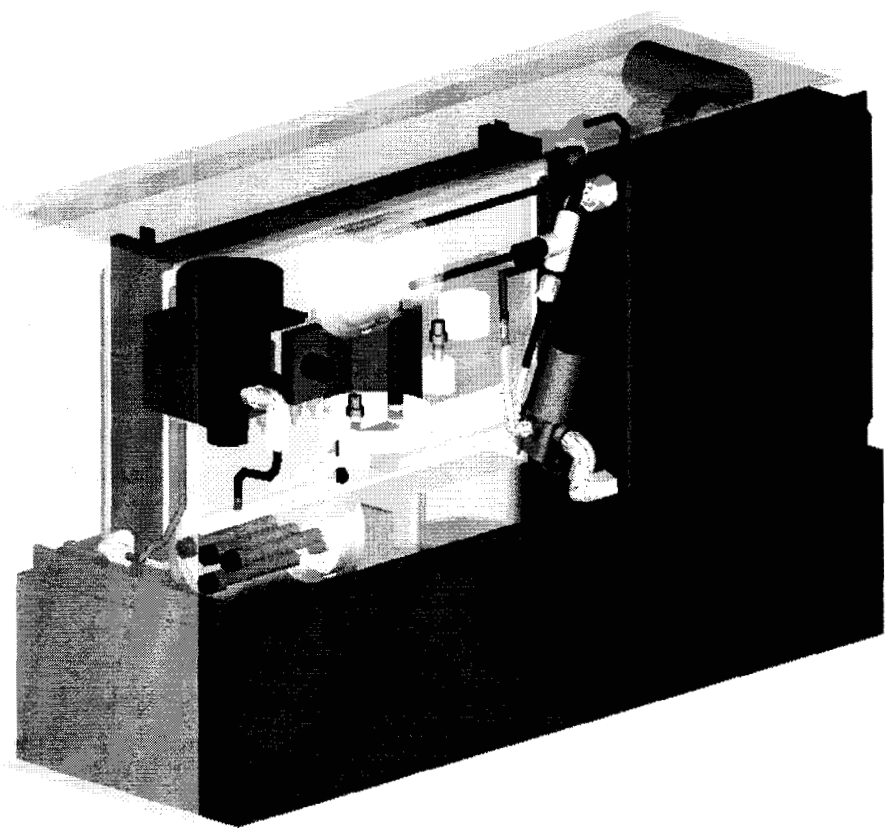
Background

- The Army currently uses four deep cycle marine batteries to provide auxiliary power to armored vehicle external test instrumentation. The batteries weigh 120 kg (270 lb) and are limited to 8 hours of operation without recharging or battery swap.

Summary of Requirements

- Power 300 W, (Continuous)
- Run Time: 100 hr
- Energy: 30,000 Whr
- Target Weight: 36 kg (80 lb) (Including Fuel)
- Other Attributes:
  - Rapid Startup
  - Field Refueling for Extended Operation
  - No Recharge Time
  - Quiet
  - Low Thermal Signature

300W Direct Methanol Fuel Cell Power Source Specifications



System Specifications

Electrical:

- Output Voltage: 20 to 30 V
- Power: 300 W
- Max Current: 15 A

Physical:

Power Source

- Dimensions: 31.5 in x 20.7 in x 11.5 in
- Mass: 55.6 kg (122.6 lb)
- Volume: 123 L (4.3 ft^3)
- Figures of Merit: 539.5 Whr/kg, 243 Whr/L

Fuel Cell System

- System Mass: 17.7 kg (39 lb)

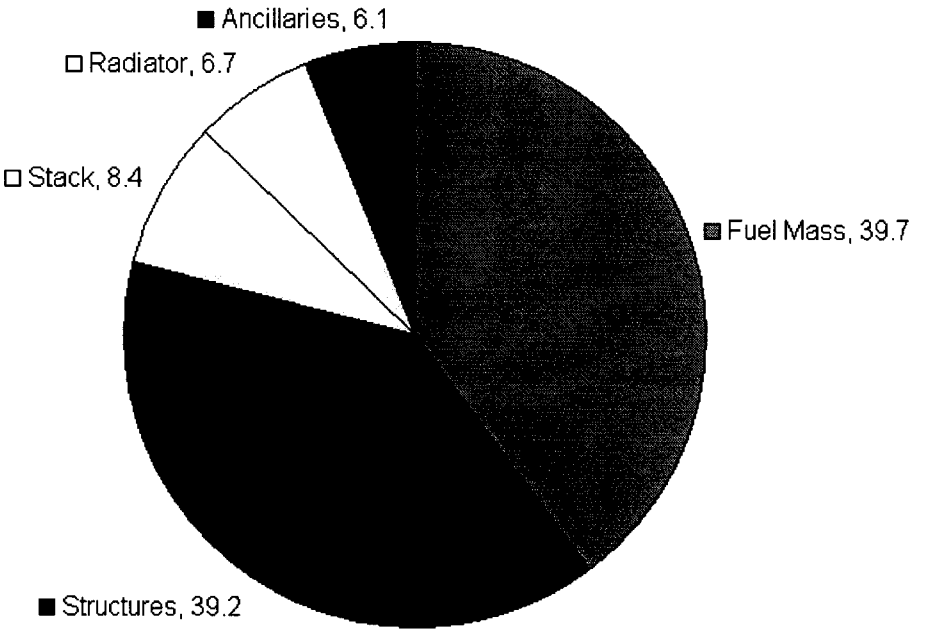
Fuel Tank

- Fuel: Methanol(Supplied from internal fuel tank)
- Capacity: 30000 Whr
- Tank Volume: 32 L (1.1 ft^3)
- Fuel Mass: 25.2 kg (55.5 lb)

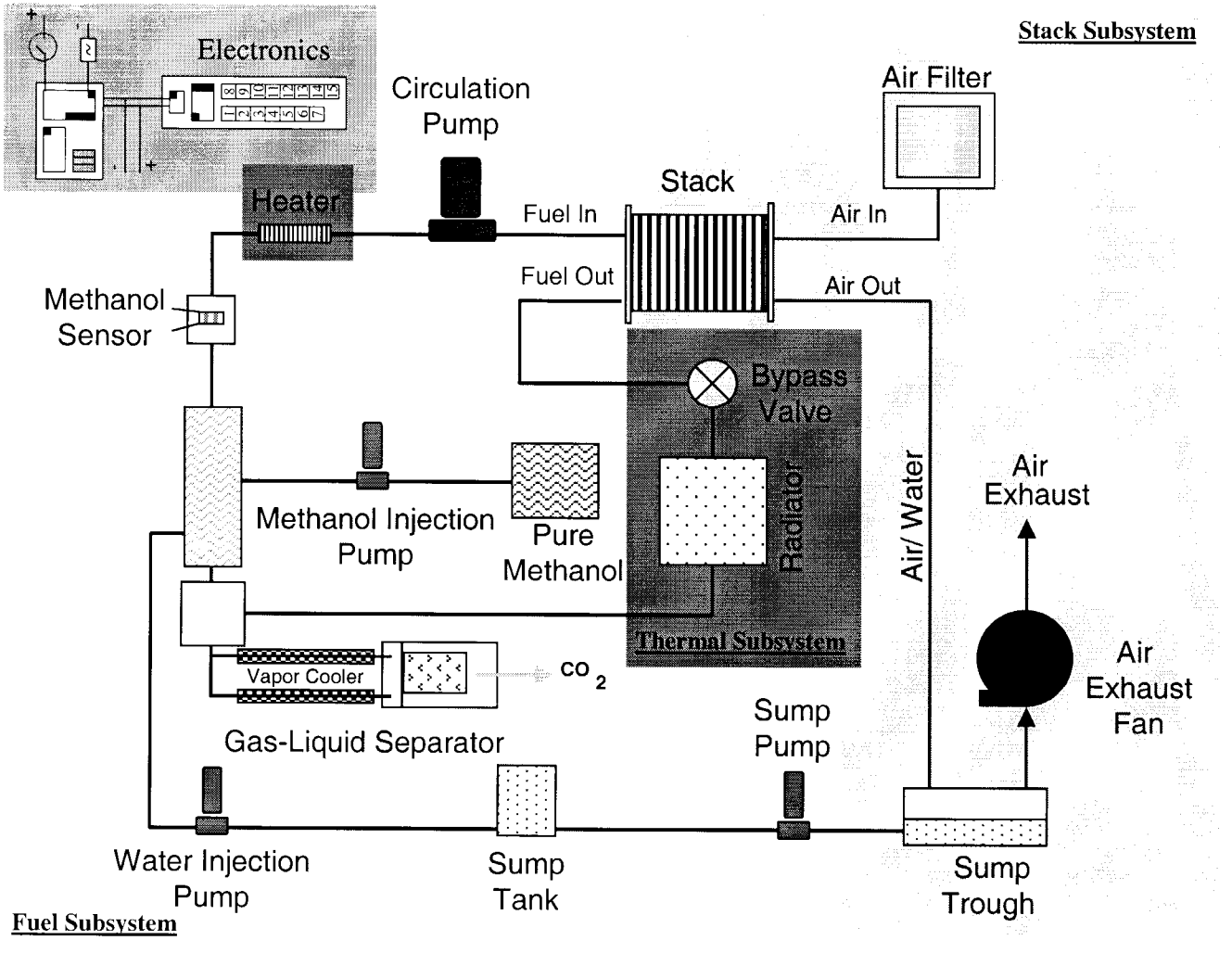
Operational Environment:

- Air Quality: High dust concentration, 20 times zero visibility (~ 5 gm/m^2 of ACS Coarse 30 microns dust)
- System Startup: Instantaneous when ambient temperature is greater than 5 °C (41 °F)
- Wet Storage: 5 to 70 °C (158 °F)
- Air Temperature: -17 to 45 °C (113 °F)
- Attitude Sensitivity: +/- 45° to vertical
- Shock and Vibration: Survive a three-foot drop on concrete.
- Unit must be protected during wash rack cycle.

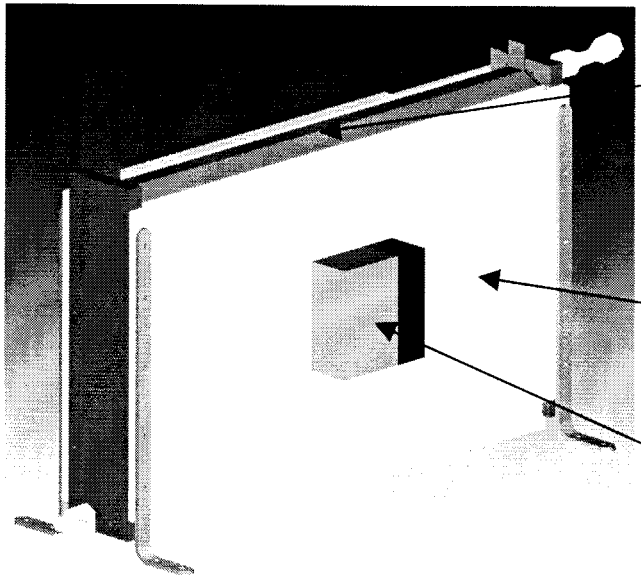
Component Percent of Power Source Mass

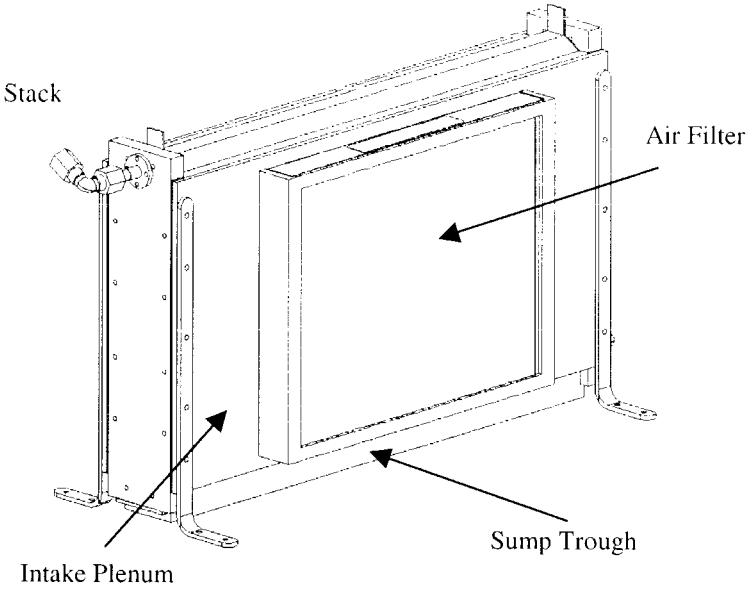


Subsystems


Stack Subsystem
Electronics
Circulation Pump
Air Filter
Heater
Stack
Fuel In
Air In
Fuel Out
Air Out
Methanol Sensor
Bypass Valve
Radiator
Air/ Water
Air Exhaust
Methanol Injection Pump
Pure Methanol
Thermal Subsystem
Vapor Cooler
CO_2
Air Exhaust Fan
Gas-Liquid Separator
Sump Pump
Water Injection Pump
Sump Tank
Sump Trough
Fuel Subsystem

Stack Subsystem

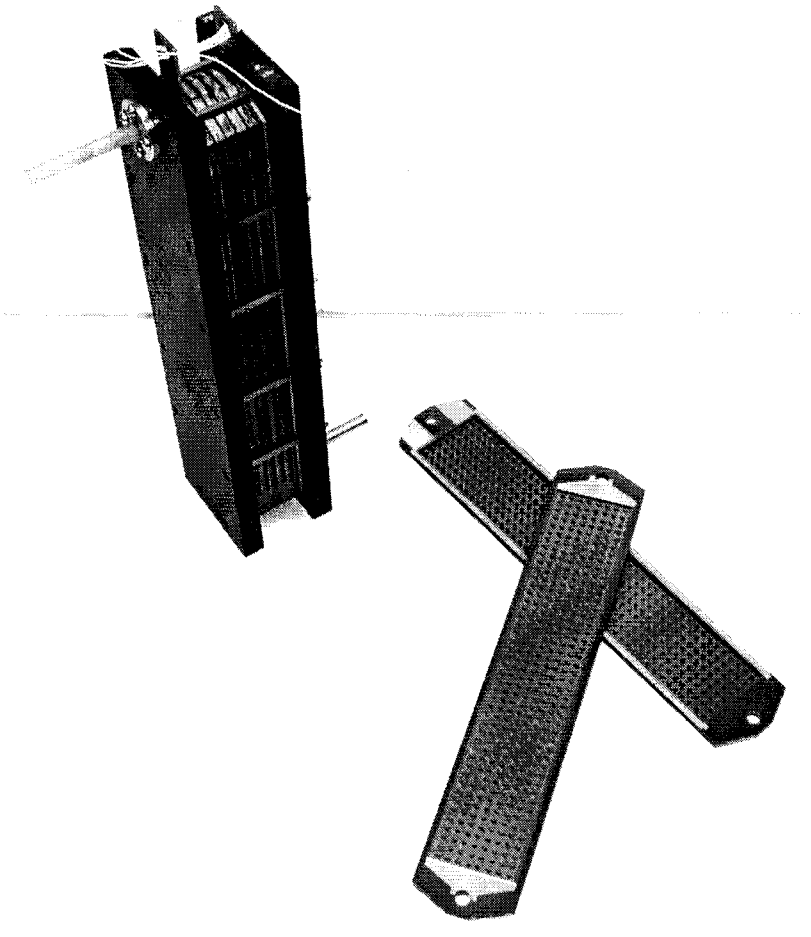




The fuel cell stack subsystem is composed of the following components:

- 81-Cell Direct Methanol Fuel Cell Stack
- Exhaust Fan
- Exhaust Plenum
- Intake Plenum
- Air Filter Assembly, Intake
- Sump Trough

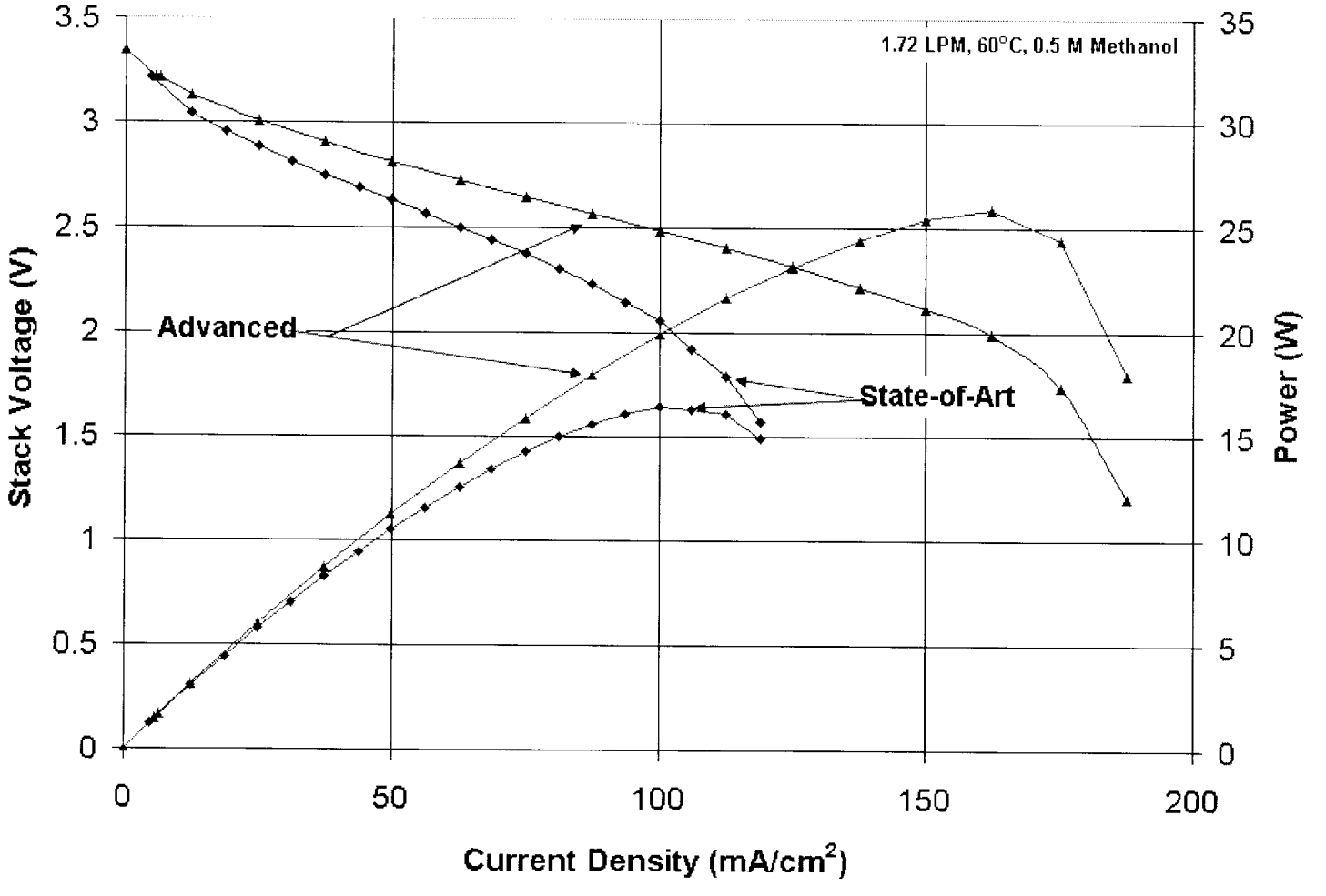
Stack Subsystem, Fuel Cell Stack



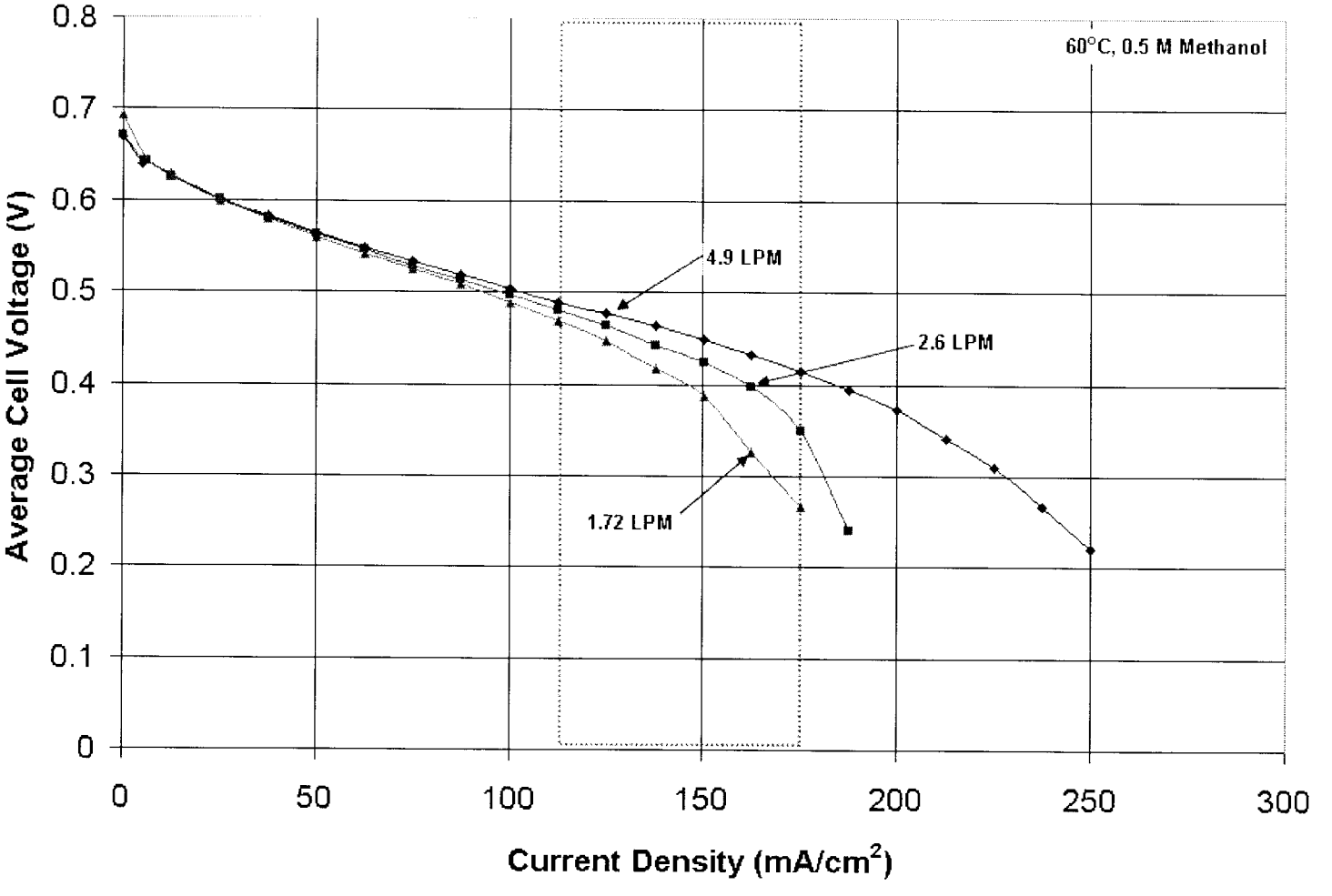
Fuel Cell Stack

- 81-cell stack
- The stack was developed under a DARPA funded program
- Low Pressure Drop Design: DP of 0.0525 inches of water with diffuser material. (5 Cell Stack)
- The stack hardware will be procured from Giner Inc. (Boston)
- MEAs Fabricated at JPL
- Peak Power: 459W (14.4A @ 31.9V)
- Mass: 6.2 kg (13.6 lb)
- Oxidant supply via exhaust fan
- Max power operating airflow rate
  - Airflow: 39.4 L/min (1.4 ft3/min)
  - Stoichiometry (at operating point): 1.74

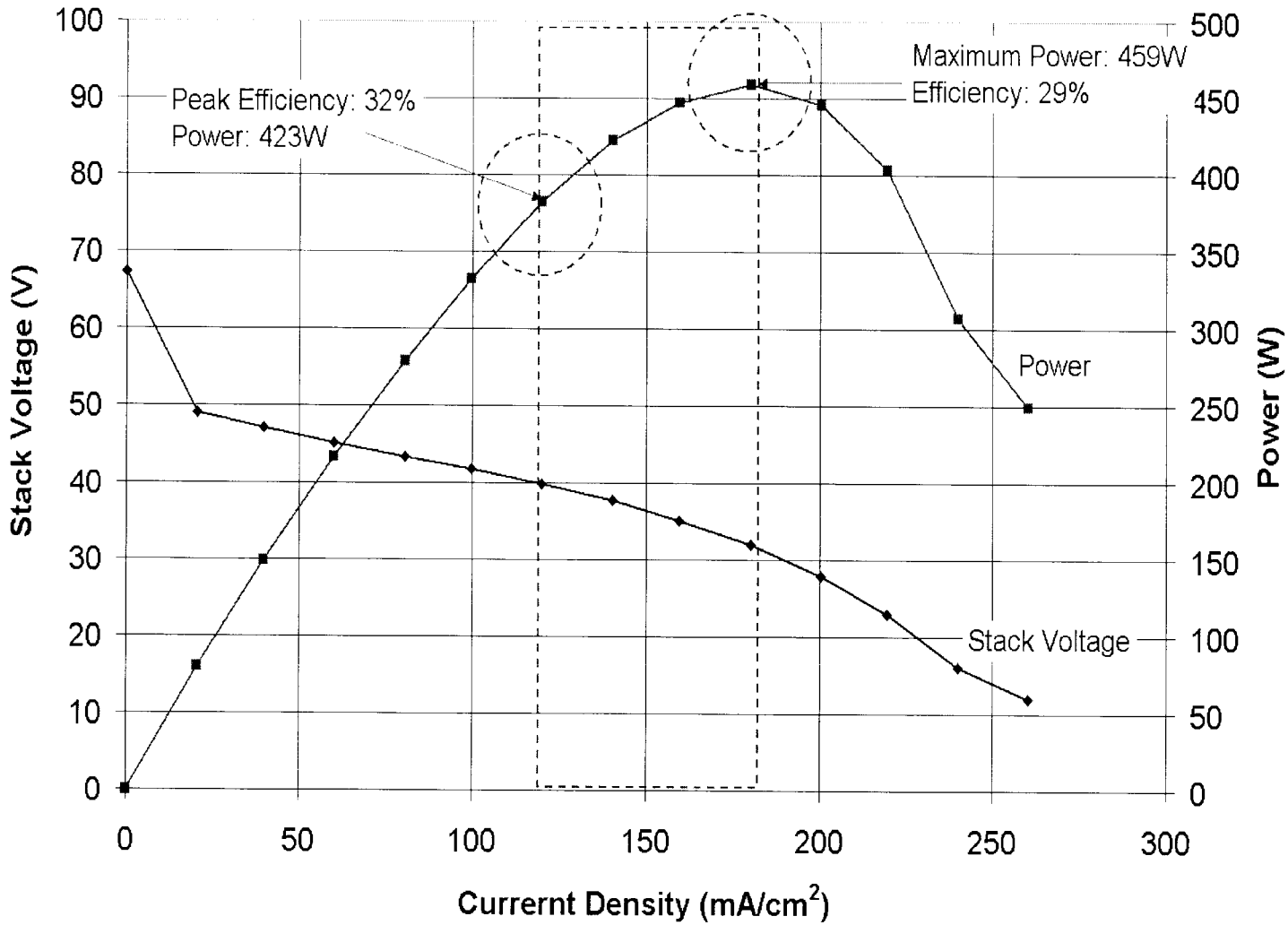
Stack Subsystem, 5-Cell DMFC Performance



Stack Subsystem, 5-Cell DMFC Performance



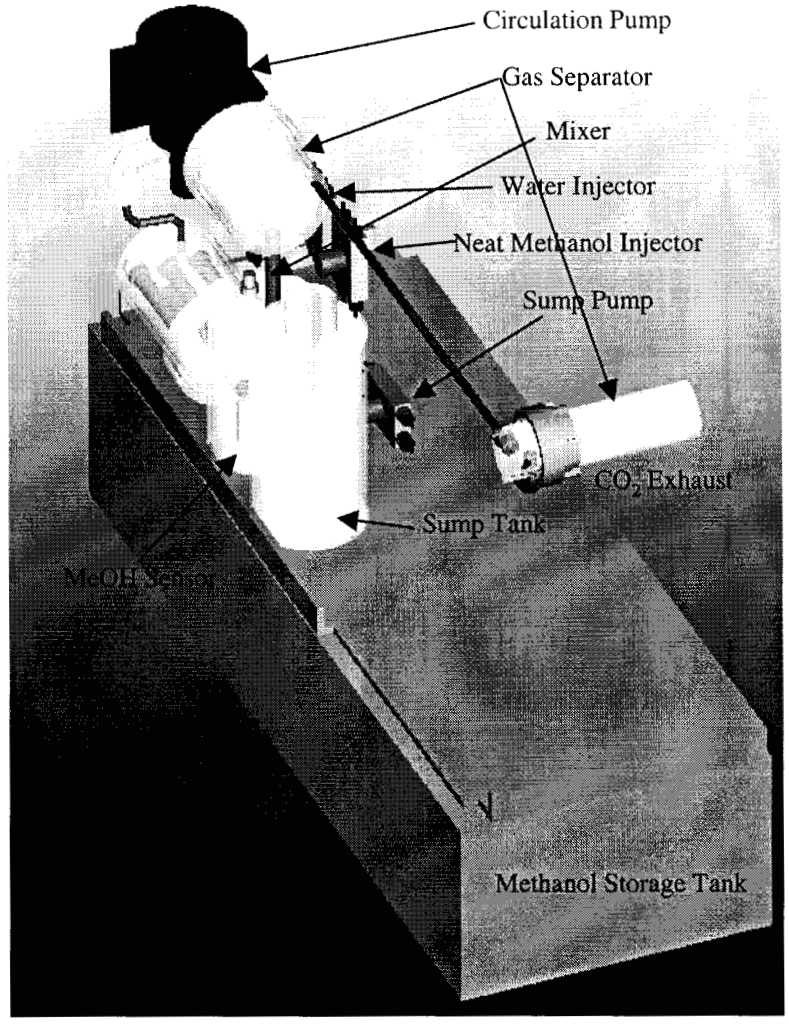
Stack Subsystem, Expected Stack Performance



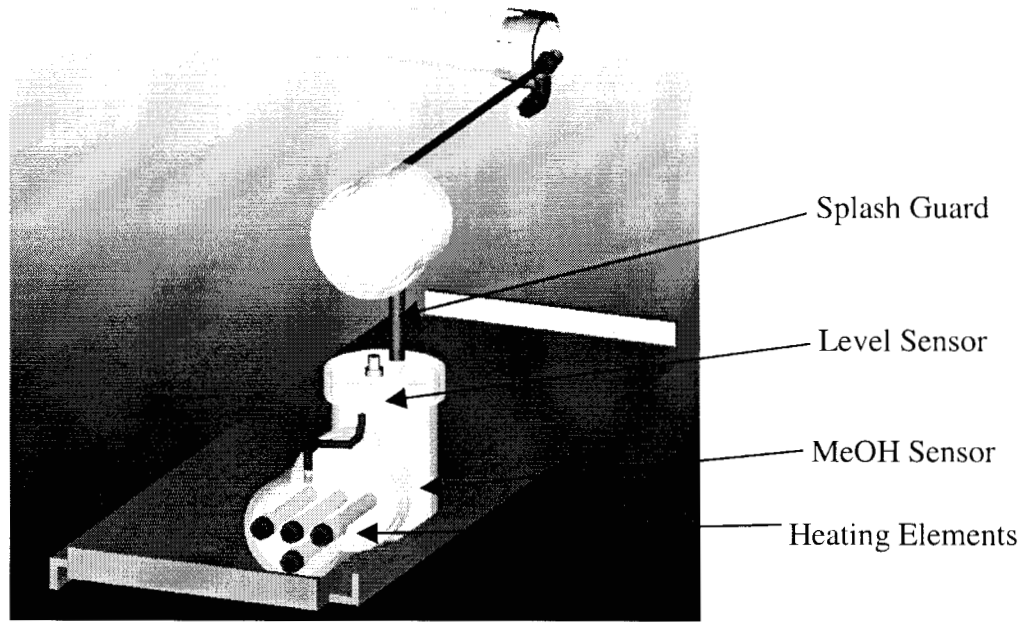
Fuel Subsystem

The fuel subsystem is composed of the following components:

- MeOH Concentration Sensor
- Mixer Separator
- CO_2 Exhaust
- Gas Separator
- Level Sensor
- Circulation Pump
- Sump Pump
- Water Injector
- Neat Methanol Injector
- Sump Tank
- Methanol Storage Tank



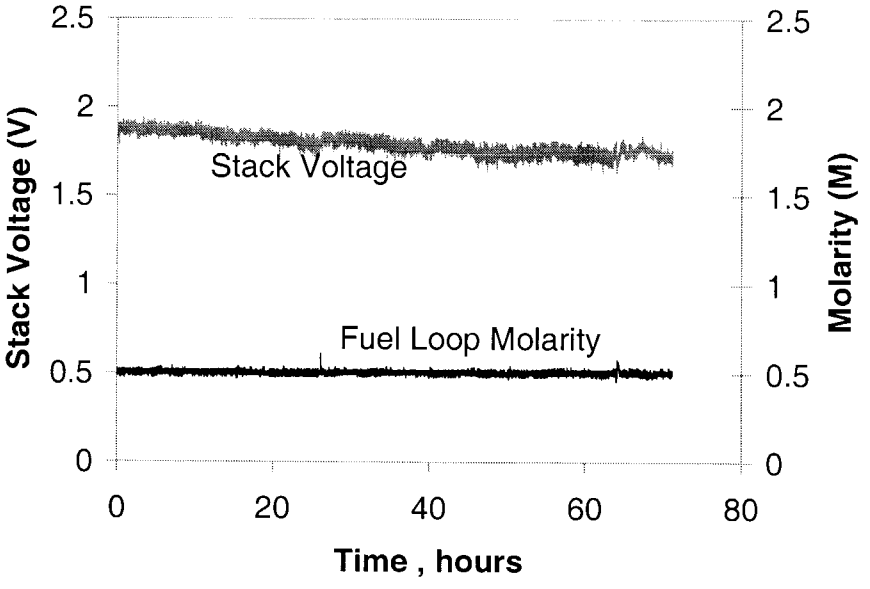
Fuel Subsystem, Gas-Liquid Separator

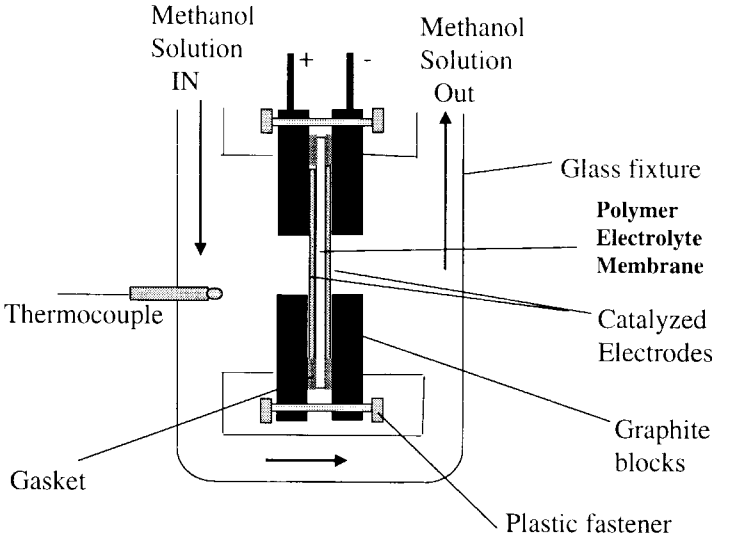


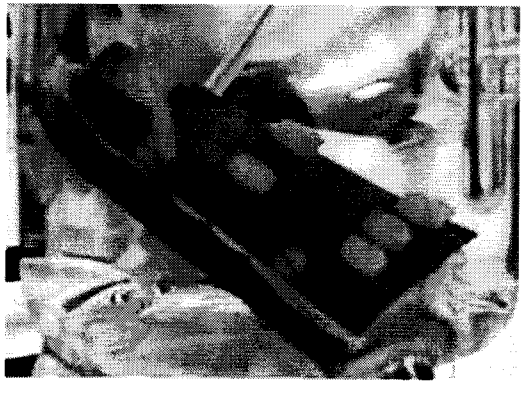
Features

- Heater, methanol sensor, level sensor co-located for maximum packaging efficiency
- Designed to meet attitude insensitivity (45° Tilt from vertical)

Fuel Subsystem, Methanol Sensor

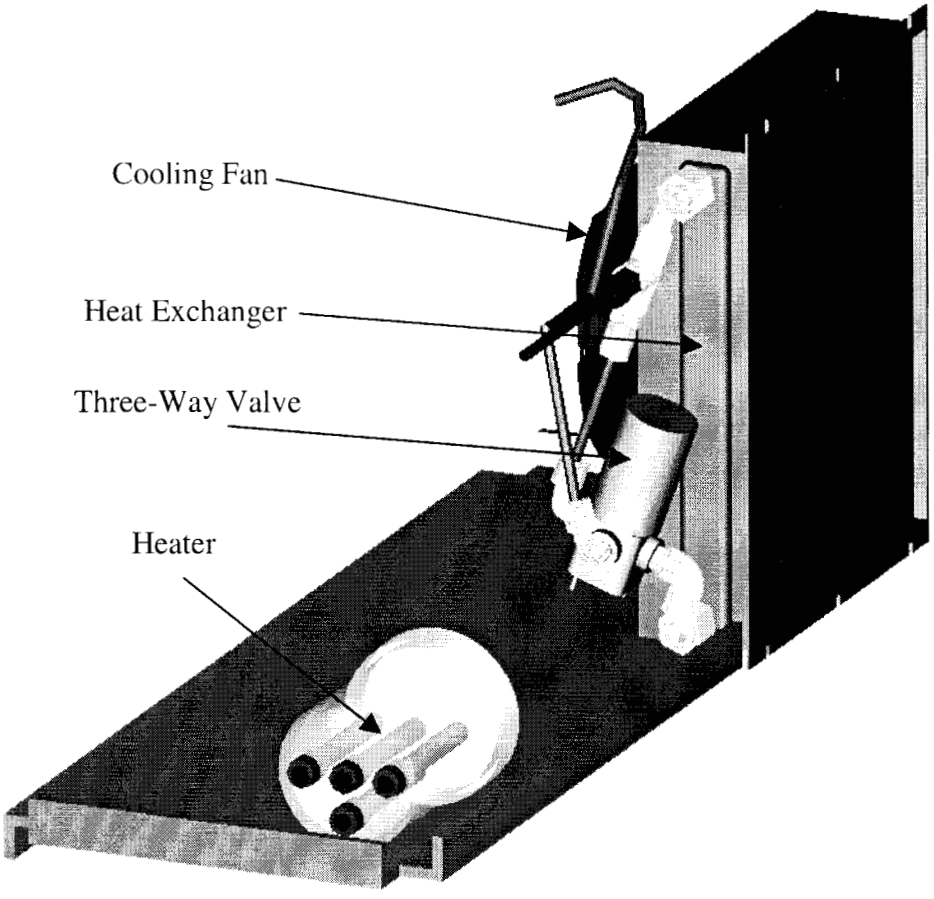






- Demonstrated
- 0.5**M** concentration maintained to +/- 0.2**M** for 70+ hours
- Integrated into 1kW DMFC system

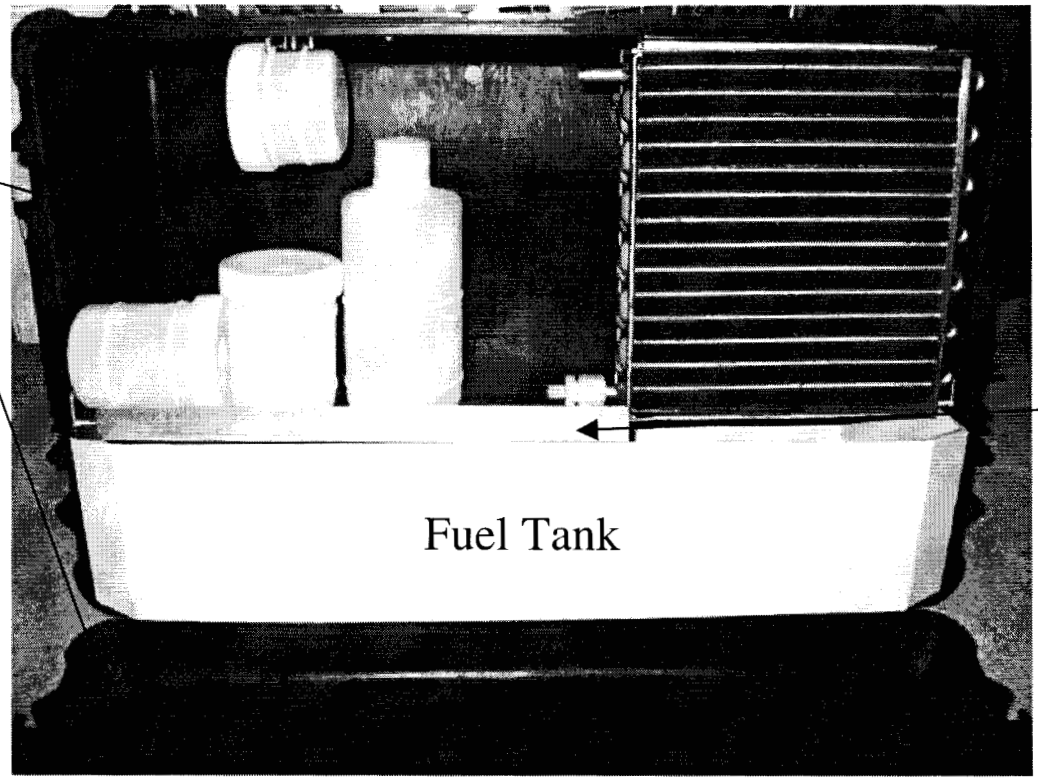
Thermal Management Subsystem



The thermal subsystem is composed of the following components:

- Heat Exchanger
- Cooling Fan
- Three-Way Valve
- Heater

System Structure

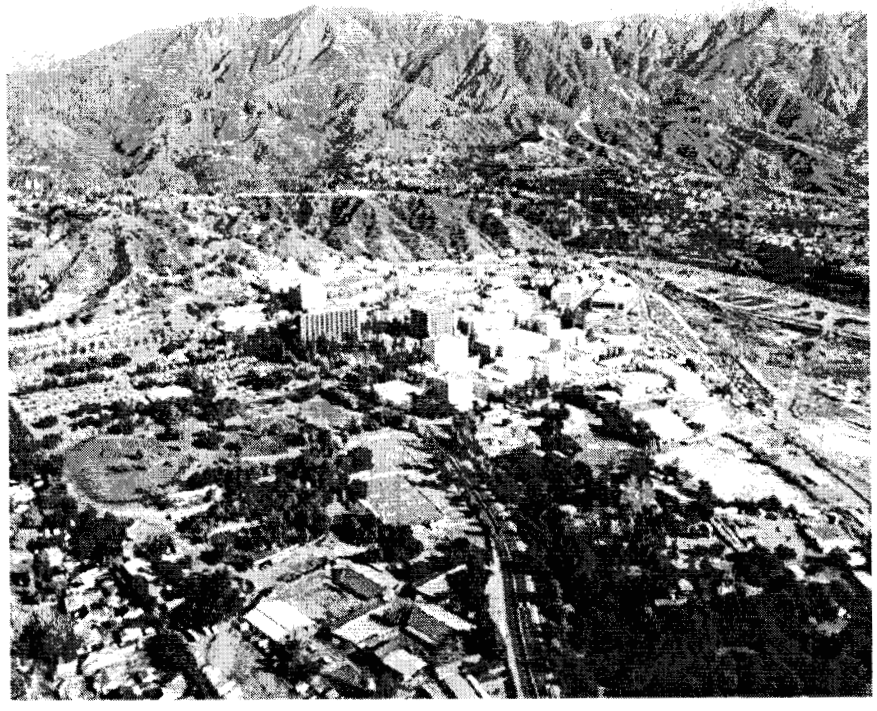


Components

- System Structure
- Power Source Housing

Summary

- At the system operating airflow of 1.7 times stoichiometry the stack power density and efficiency are expected to be 55 mW/cm^2 and 33% respectfully.
- The system volume is 123 L
- The system mass is 55.6 kg (CBE)
- The CBE figures of merit for this power source are 540 Whr/ kg and 243 Whr/ L for the specific power density and volumetric power density respectfully.
- System integration to be completed this November '03
- Field demonstration scheduled for February '04

Acknowledgements

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