THE
JPL DIRECT METHANOL LIQUID-FEED
POLYMER ELECTROLYTE MEMBRANE (PEM)
FUEL CELL

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Recently, there has been a breakthrough in fuel cell technology in the Energy Storage Systems Group at the Jet Propulsion Laboratory with the development of a direct methanol, liquid-feed, solid polymer electrolyte membrane (P EM) fuel cell. The fuel cell operating at 90^{o}C utilizes a 3% aqueous methanol solution as the fuel with air (02) as the oxidant. The only products are water and C02. The fuel cell electrode assembly prepared by Giner Inc, based on the JPL technology, was scaled up from 25 cm^2 to 160cm^2. The methanol/water fuel replaces the H2 gas or methanol-reformed-to-H2 gas, both of which are considered impractical for moderate power consumer use, e.g., vehicles, UPS, lawnmowers, battery replacement in Army BA5590 radios, etc. To date no organization, U.S. or foreign, has been able to operate directly with liquid methanol and come close to the output levels exhibited by the JPL system (300ma/cm^2 at 0.5 Vat 60-90^{o}C).

The methanol liquid-feed, solid polymer electrolyte (PEM) design has numerous system level advantages over the gas-feed design. These include: a) elimination of fuel vaporizer and its associated heat source and controls, b) elimination of complex 'humidification and thermal management systems, c) use of the liquid methanol/water in the dual purpose as fuel and as an efficient stack coolant," and d) significantly lower system size, weight and temperature than existing fuel cell systems. Also, the PEM cell design does not suffer from the disadvantages of the phosphoric acid liquid electrolyte cell design which is also complex, voluminous and massive. The use of PEM eliminates the problem of troublesome shunt currents and also eliminates problems associated with corrosion of cell" components. A list of the advantages is given in Table 1.

The solid polymer (PEM) membrane employed in the JPL liquid-feed fuel cell separates the anode (negative) and cathode (positive) chambers. A 3% aqueous solution of methanol (20 psi) is fed into the fuel chamber (anode) and 02 or air (20 psi) is supplied to the cathode (Figure 1). The water produced at the cathode is circulated back to the reservoir where it is injected with methanol. The unused methanol/water solution from the anode chamber is also circulated back to the reservoir. The CO_2 product is released as a gas as shown in Figure 2.

Laboratory versions, of the JPL PEM cell, operating directly on a 3% methanol in water solution at a temperature of 60- 90^{o}C, have delivered an output of 0.50 V at 300 mA/cm^2 using oxygen. The performance has improved since March 1992 when the breakthrough occurred (Figure 3). This output at the cell level is quite high relative to that of prior direct oxidation methanol fuel cells (power density up by factor of 20). Laboratory cells of 2"X 2" (7,.7 amps continuously) and 4" x 6" (50 amps continuously) provided by Giner Inc. have been demonstrated (Figure 4). The next step of scaling up to a 3 cell design will provide an understanding of the thermal and water circulation issues.

A 5kW liquid-feed methanol fuel cell stack with the present demonstrated overall 24% efficiency (voltage + fuel) is projected to be 8" x 8" x 32". Enhancement of the stack with an improved PEM and catalyst modifications to achieve a >40% efficiency is projected to be 8"X 8" x 17".

Methanol is produced from natural gas and is already available at some service stations on the west coast. However, JPL has tested USC-developed alternative higher boiling point fuels such as trimethoxymethane (TMM) as potential substitutes for methanol with results equivalent to methanol. Caltech is developing several advanced catalysts to improve the direct oxidation of methanol and reduction of 02. They are also involved with development of catalysts for direct oxidation of hydrocarbon fuels.

Detroit Center Tool (DCT), a privately-owned company, has purchased a license from Caltech for the commercial rights to this technology (patent applied for). Through a Technology Affiliates agreement, JPL will demonstrate a pre-prototype 5 kw fuel cell system in 2 years and an advanced technology prototype system in 4 years.

There are several challenges that must be met before commercialization can be realized. These include the technical challenges of improving rate, and voltage performance as well as scaling up the design and reducing cost to a viable level. The issues and strategies are given in Figure 5.

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TABLE 1: ADVANTAGES OF THE JPL DIRECT METHANOL, LIQUID-FEED PEM FUEL CELL

Methanol /Water Mixture Fed Directly Into Anode Chamber

Simplicity Of System - Minimal Components
No Reformer - No Hydrogen Storage

Simplified Thermal And Water Management

C02 And Water Are The Only Products

Two-Phase System Enables CO_2 Removal

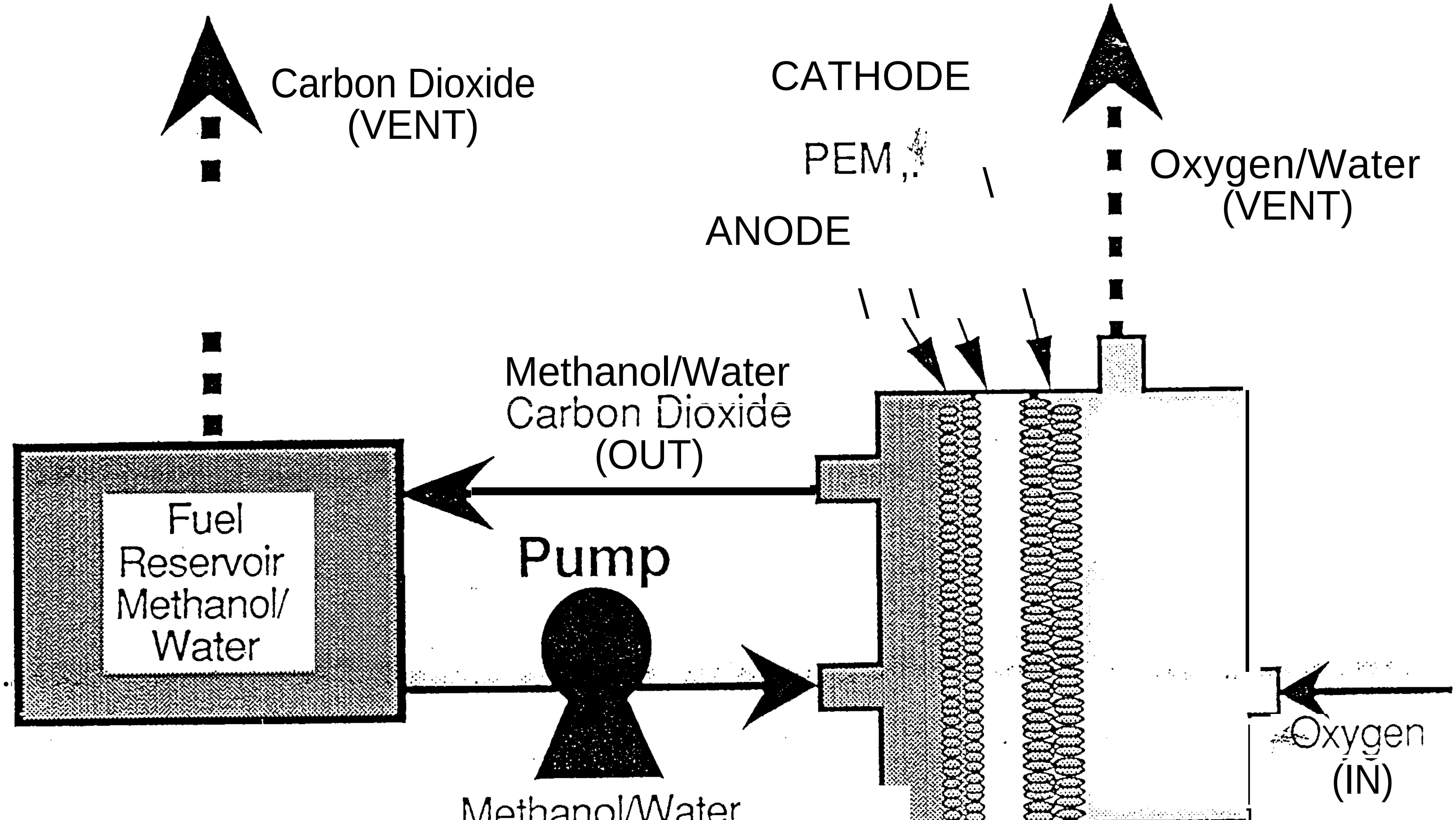
No Corrosive Electrolytes

Amenable To Scale-Up

Operation At Low Temperature (70 -90 c)

Methanol Infrastructure In Place

FIGURE 1: DIAGRAM OF THE JPL DIRECT METHANOL LIQUID-FEED FUEL CELL



300 ma/cm^2
0.5V/cell

FIGURE 2: SCHEMATIC OF JPL DIRECT METHANOL LIQUID-FEED FUEL CELL SYSTEM

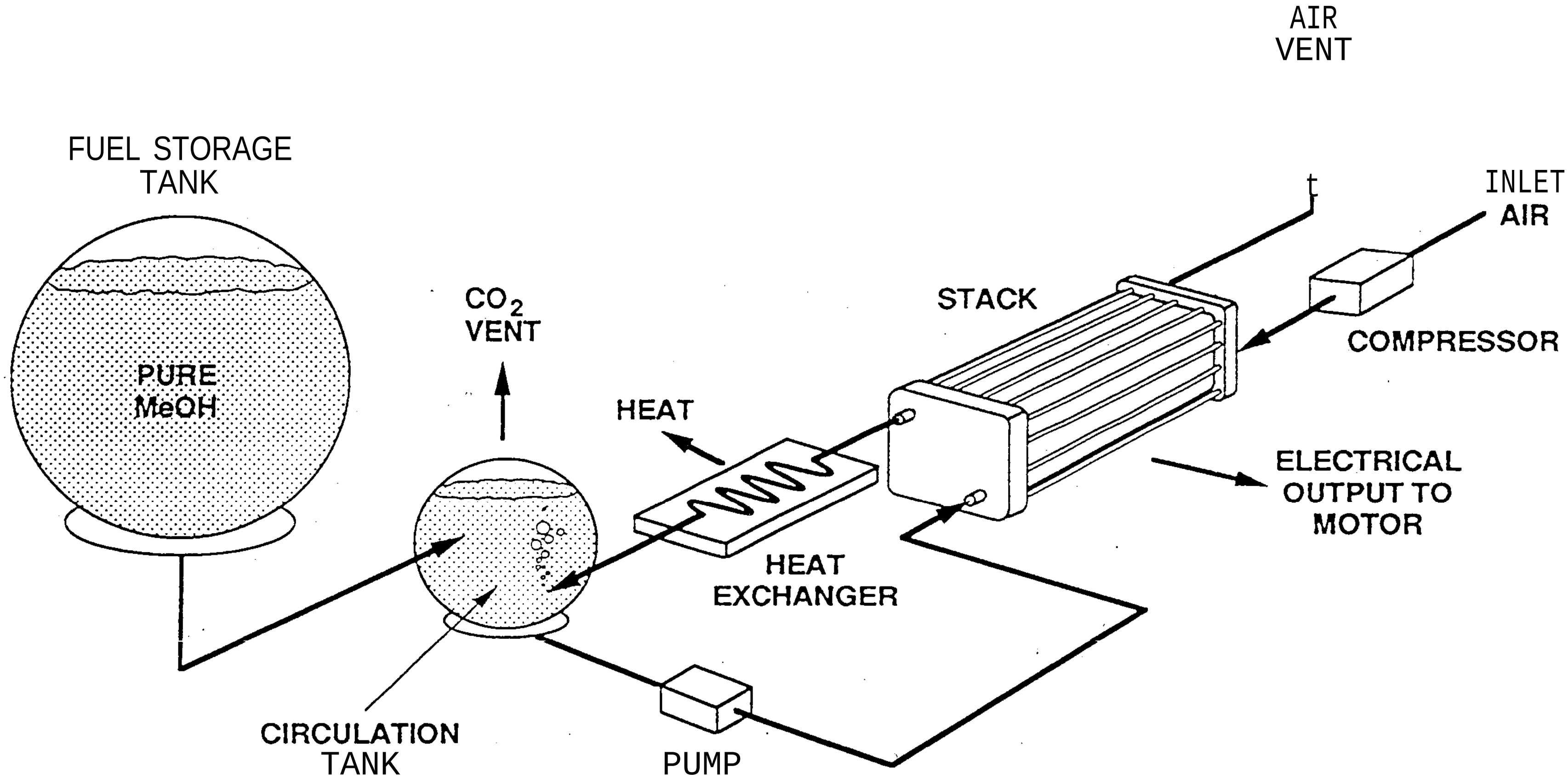
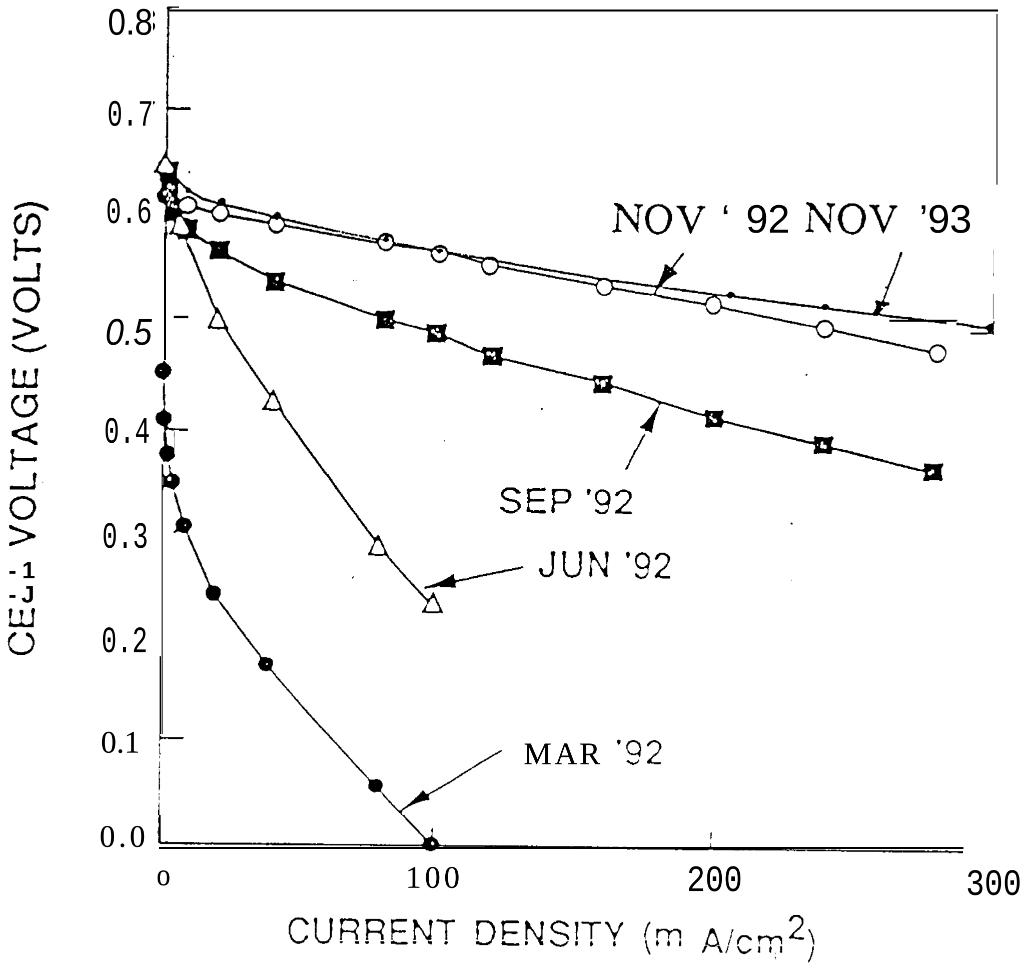
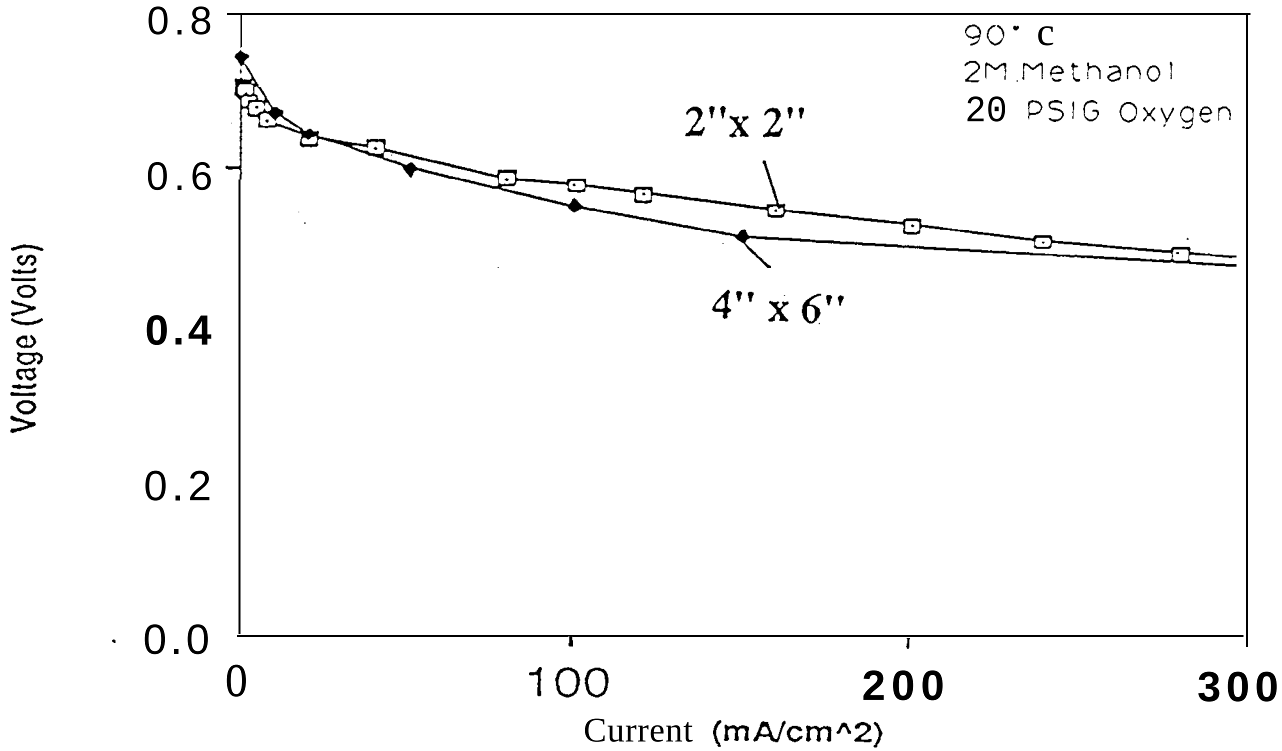


FIGURE 3: IMPROVEMENTS IN CELL PERFORMANCE



" SIGNIFICANT PROGRESS DURING FY 1992

FIGURE 4: PERFORMANCE COMPARISON OF **2"X2"** AND **4"X6"** CELLS



* No Significant Performance Loss In Scale-Up

FIGURE 5: ISSUES AND STRATEGIES

ISSUE	STRATEGY
Chemistry and Materials	
IMPROVE ELECTRICAL PERFORMANCE	IDENTIFY ADVANCED CATALYSTS
ENHANCE EFFICIENCY FROM 25 TO 40 %	REDUCE FUEL CROSSOVER
REDUCE COST	DEVELOP LOW COST MEMBRANES & CATALYSTS
Engineering	
SCALE UP STACK TECHNOLOGY FROM 30W TO 5 KW LEVEL	DEV. DESIGNS FOR E'CHEM THERMAL AND FLUID MGMT. INCREMENTAL STACK DEV.
COMPACT AND EFFICIENT EV SYSTEM DEV.	CONDUCT SYSTEM DESIGN TRADE-OFFS HIGH PERFORMANCE ANCILLARIES