REGENERATIVE FUEL CELL SYSTEMS FOR SPACE STATION

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ABSTRACT

Regenerative fuel cell (RFC) systems are one of the leading energy storage candidates for Space Station. Key design features include its advanced state of technology readiness and high degree of system level design flexibility. Technology readiness has been demonstrated through extensive testing at the single cell, cell stack, mechanical ancillary component, subsystem, and breadboard levels. Design flexibility characteristics include independent sizing of power and energy storage portions of the system, integration of common reactants with other Space Station systems, and a wide range of various maintenance approaches. These design features have led to selection of a RFC system as the sole electrochemical energy storage technology option for the Space Station Advanced Development Program.

INTRODUCTION

The RFC program was initiated in 1979 by OAST to bring fuel cell and electrolysis technology to a level of flight readiness by 1987. The program has been a joint effort by NASA Lewis Research Center (LeRC) and NASA Johnson Space Center (JSC). The LeRC program has been directed toward development of alkaline technology, with fuel cell work being conducted at United Technologies Corp. (UTC) and electrolysis work at Life Systems, Inc. (LSI). The program at JSC has been directed toward both acid SPE fuel cell and electrolysis technology, the work conducted at General Electric Company (GE). More recently, the work sponsored out of LeRC has been aimed at alkaline cell component technology, specifically in the areas of electrode catalysts, unitized electrode assemblies, cell frames, separator matrices, feed-water cavity matrices, electrolyte reservoir plates (ERP's), and decay modeling. The JSC work has focused on both alkaline and acid SPE system technology, mainly in the areas of mechanical ancillary components and breadboard demonstrations.

A detailed in-house design study has been performed at LeRC to investigate the merits of the alkaline and acid SPE technology options. The results of this study have shown the alkaline fuel cell - alkaline electrolysis RFC to be the best option for further development; in terms of system complexity, performance, development cost, and risk. The end-item deliverable of this program will be a 10 KW alkaline engineering model system (EMS) by 1987. The system shall be capable of demonstrating full integration with autonomous control, high voltage operation ($\geq$ 100 Vdc) and good overall round-trip electrical efficiency ($\geq$ 55 percent).

TECHNOLOGY READINESS

FUEL CELL

Alkaline fuel cells are a flight-qualified aerospace technology. An extensive data base has been generated through the Shuttle-Orbiter program, both in qualification testing and in actual mission performance. Improvements to this technology, in the electrochemical and mechanical ancillary component portions of the system, are already under way.

In the electrochemical cell component area, key items are the cell frame, separator matrix, ERP, and anode catalyst. Replacing the present fiberglass/epoxy frame with polyphenylene sulfide (PPS) and the current asbestos matrix with potassium titanate (PKT) are both aimed at carbonate reduction, which will lower the degradation rate of the cell by an order of magnitude and extend life. Substitution of graphite for the present nickel ERP will reduce cell weight almost in half, while utilizing a platinum-on-carbon anode catalyst in place of platinum/palladium will also reduce degradation and extend life. Ongoing endurance test results for a six-cell stack and four-cell stack at UTC are shown in Figures 1 and 2, respectively. The six-cell stack incorporates a platinum-on-carbon catalyst, while the four-cell stack is composed of a PKT matrix, graphite ERP, and platinum-on-carbon catalyst. PPS frames in varying combinations with these other electrochemical cell component improvements are being tested under Navy and UTC IR&D programs.

Key items in the mechanical ancillary component area are the dual pressure regulator, thermal control valve, coolant pump, and hydrogen pump/separator. Reduction of internal wear to those components with moving parts is the major activity. Specifically, improved bearing lubricant seals and advanced bearing concepts are under investigation. Endurance testing will verify feasibility.

ELECTROLYSIS

Alkaline electrolyzers are not flight-qualified. However, a substantial data base exists for life support and terrestrial hydrogen production applications. As with alkaline fuel cells, improvements to the electrochemical and mechanical ancillary component portions of the system are under way.

In the electrochemical cell component area, key items are unitized electrode assemblies and the feed-water cavity matrix. Unitized core construction improves cell sealing reliability and reproducibility. Replacing the current asbestos feed-water cavity matrix with a porous hydrophobic sheet will allow passage of any evolved gaseous hydrogen from the feed-water cavity to the hydrogen cavity. Ongoing performance of present aerospace technology has already been demonstrated, as can be seen in Figure 3. Test results for a six-cell stack incorporating unitized electrode assemblies are shown in Figure 4. Successful scale-up of cell active area has been verified in a DOE program at LSI.

Key items in the mechanical ancillary component area are the coolant control assembly, fluids control assembly, and fluids pressure controller. Each of these components combines several functions (valves, sensors, etc.) in order to simplify the subsystem. Successful endurance testing continues at LSI under a NASA Ames Research Center (ARC) program.

DESIGN FLEXIBILITY

SEPARATE SUBSYSTEMS

A simple RFC system schematic diagram is shown in Figure 5. The system consists primarily of three subsystems; fuel cell, electrolysis, and reactant storage. The power portion of the system is the fuel cell and electrolysis subsystems, both separate units. The energy storage portion is the reactant storage subsystem. Because of the separate nature of these subsystems, independent sizing for a particular mission application is possible. This is not true of battery systems, where reactants are stored in the electrodes themselves. The RFC system is thus very adaptable to different peak and emergency power conditions, where power loads (KW) and energy storage loads (KW-hr) may not be directly related and could vary substantially for the Space Station.

INTEGRATION WITH OTHER SYSTEMS

The RFC system is amenable to both closed loop (internal reactant supply/demand) and open loop (external reactant supply/demand) operation. The former is typical of battery systems, while the latter type of operation allows for integration with other Space Station systems through sharing of common reactants. The other systems include life support, propulsion, and possibly space manufacturing. Water can therefore be the logistic fuel for all these systems, either used directly or readily converted to gaseous hydrogen and oxygen through electrolysis. Scavenging of residual Shuttle-Orbiter cryogenics may be another form of integration possible with an open loop system.

MAINTENANCE APPROACHES

Separate subsystems also make possible various maintenance schemes. The mechanical ancillary components as opposed to the electrochemical portions of the system are generally regarded as the least reliable items. Depending on redundancy requirements, packaging of system elements can be performed in such a way as to minimize the impact of a failure. For those items with the least reliability, parallel plumbing with multiple mechanical ancillary components may be the optimum approach. The orbital replacement unit (ORU) philosophy will dictate which grouping of system elements is the most advantageous. Any arrangement from an entire system to an individual component is possible. Replacement and introduction of new technology in both the electrochemical and mechanical ancillary component portions of the system thus becomes more likely as well.

CONCLUDING REMARKS

Regenerative fuel cell systems offer many advantages over other competing energy storage systems for the Space Station application. Technology readiness has been demonstrated through partial flight qualification and a significant endurance test data base for the fuel cell and electrolysis subsystems. The integrated system offers an inherent design flexibility due to the separate nature of the reactant storage subsystem. These design features have led to selection of an alkaline RFC as the electrochemical energy storage system technology option for the Space Station Advanced Development Program.

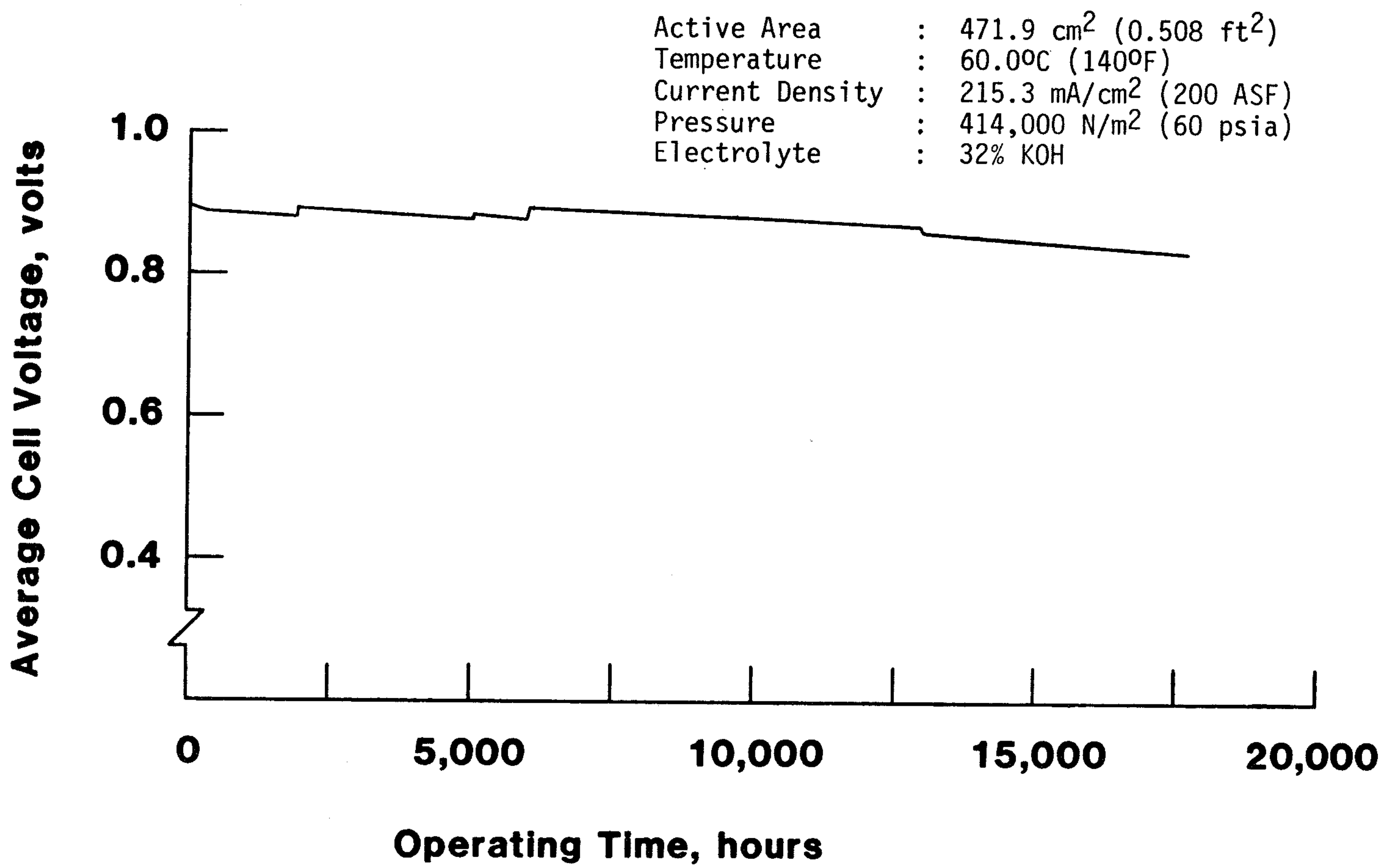

Figure 1. UTC six-cell stack endurance test

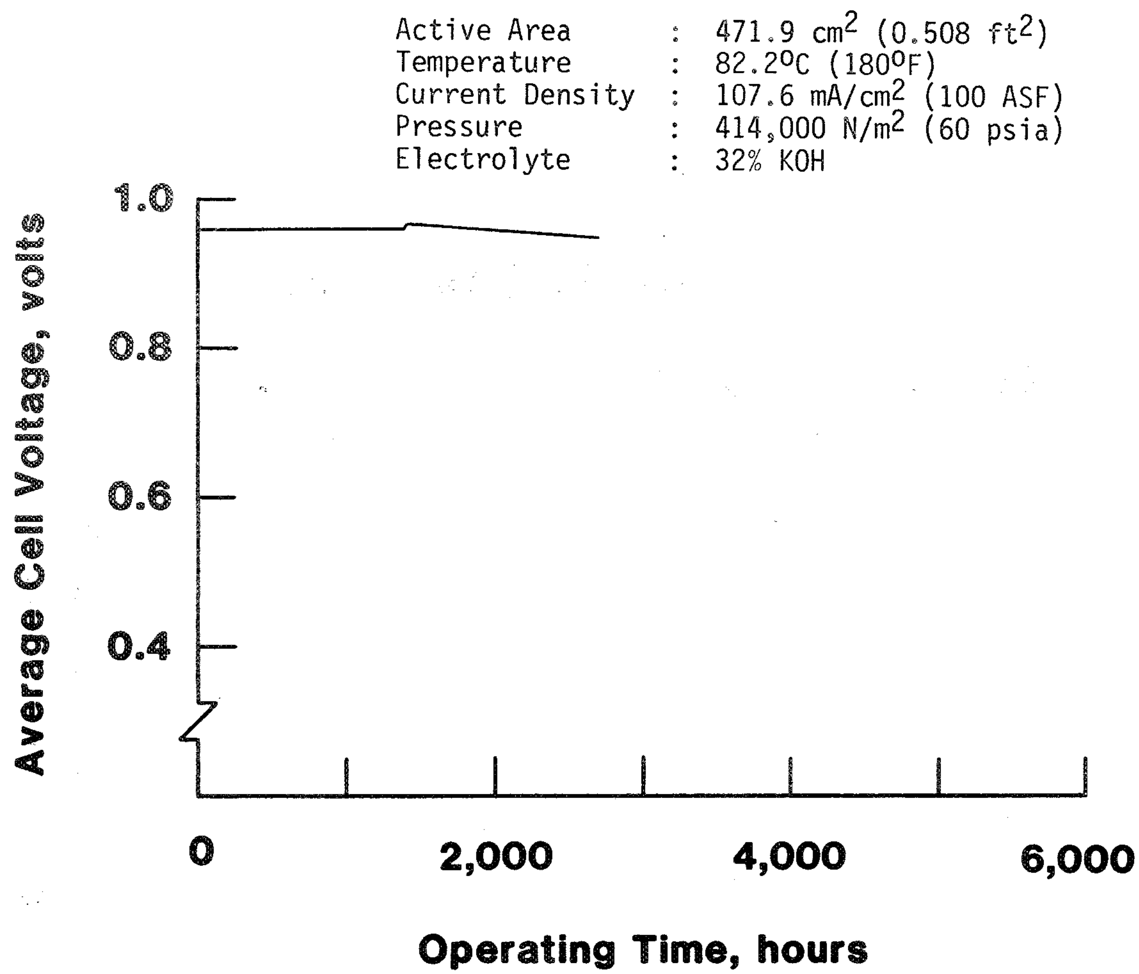

Figure 2. UTC four-cell stack endurance test

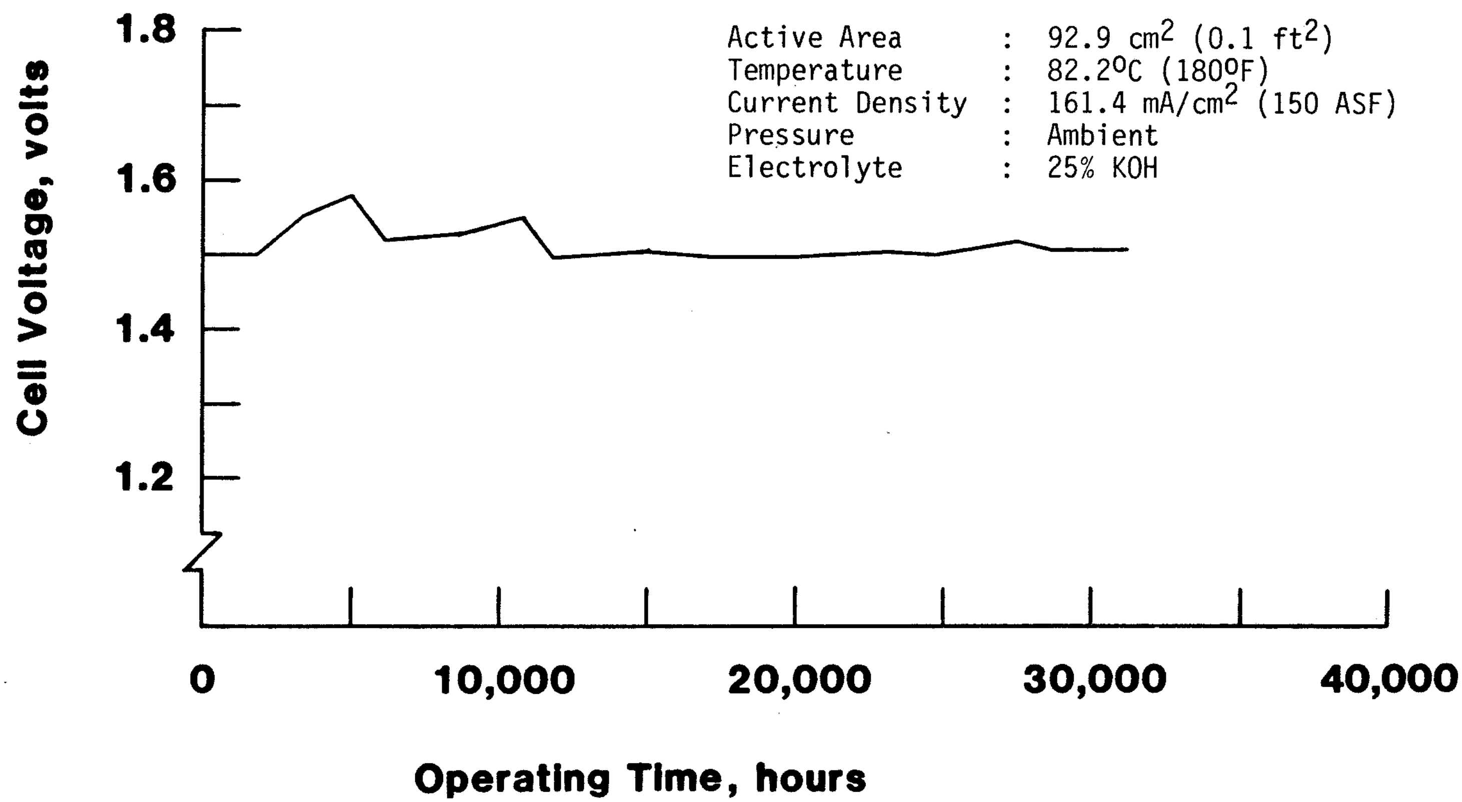

Figure 3. LSI single cell endurance test

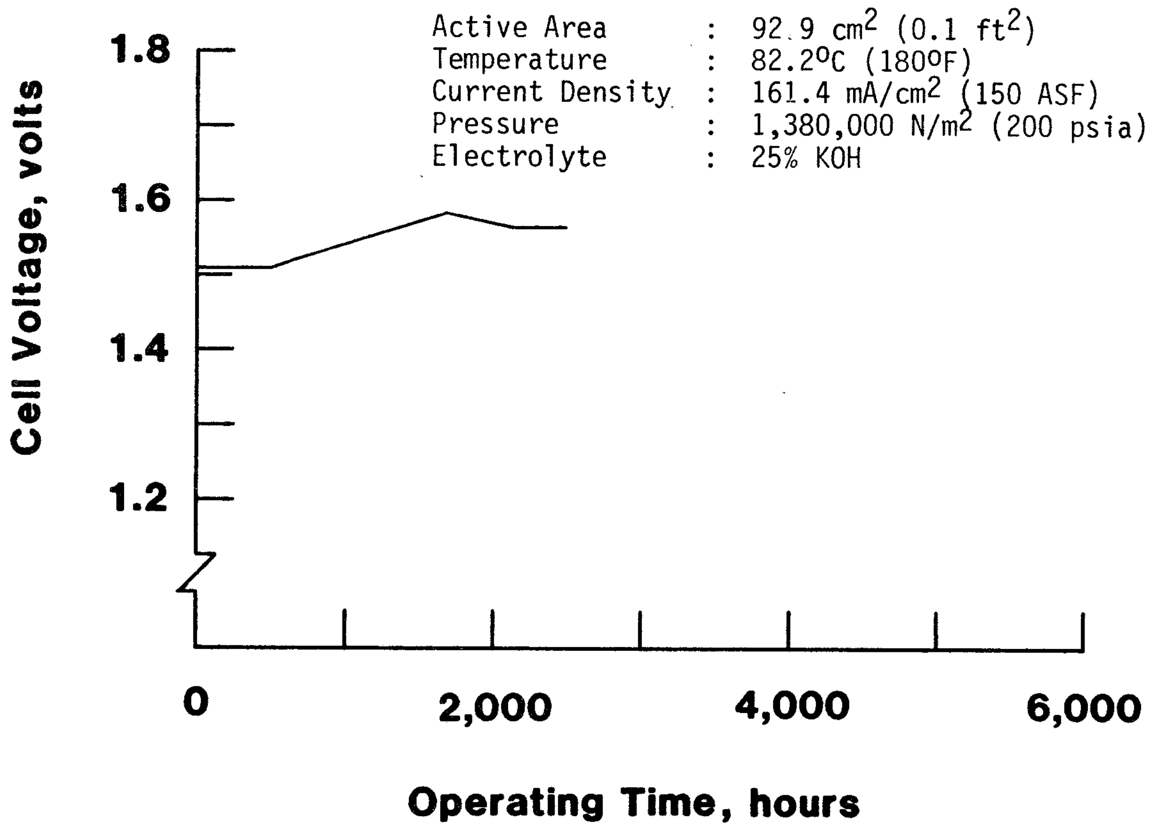

Figure 4. LSI six-cell stack endurance test

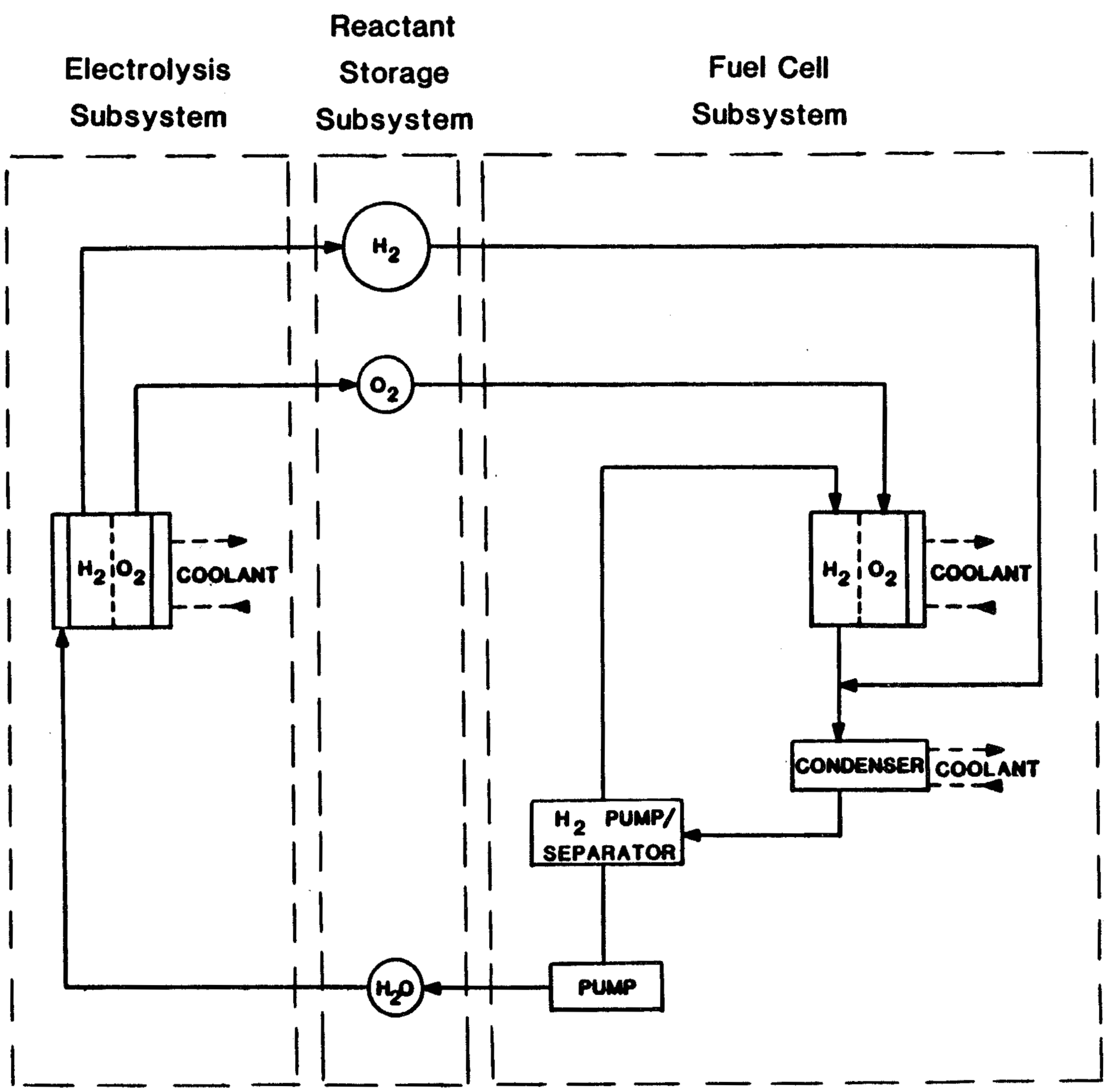

Figure 5. RFC system schematic diagram