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Center For Fuel Cell Research and Applications Development Phase

Final Report

MASTER

Houston Advanced Research Center
4800 Research Forest Drive
The Woodlands TX, 77381

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DISCLAIMER

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Final Report

Introduction

This project was undertaken by the Houston Advanced Research Center (HARC) to develop a program concept for the Center for Fuel Cell Research and Applications (CFCRA). This project was supported by the Department of Energy under project DE-FC36-98GO1036-A000.

As a result of the support provided by the Department of Energy, the staff of the Houston Advanced Research Center was able to accomplish a number of tasks leading to the development of the CFCRA. Principal among these were the following:

- Development of a concept for an industry driven center that provides needed information regarding the operational characteristics and applications of state of the art commercial and pre-commercial PEM fuel cell systems.
- Development of a concept white paper and educational overheads on the CFCRA
- Visits to and interviews with most US manufacturers of PEM fuel Cells
- Interviews and discussions with more than 20 US companies representing a range of industry sectors, including Utilities, Airlines, Municipalities, Power Marketing, Retailing, Energy, Financial, and others including local, state and Federal governments A full list of meeting contacts is presented in Appendix A.
- Development of a planning rationale for the creation of the CFCRA covering construction, safety, instrumentation, and many other aspects.
- Development of educational information for Industry representatives.
- Development of a document for NASA JSC to provide HARC access to NASA technology and fuel cell expertise.

In this report the activities conducted under agreement will be presented. In many cases the full substance of the items described below are presented in the attached appendices.

Designing the Program Concept

During the period of performance HARC was able to arrange and conduct visitations to several fuel cell developers and manufacturers. These included Plug Power in Latham, New York; IFC/ONSI in South Windsor Connecticut; Energy Partners in West Palm Beech, Florida and Ballard in Vancouver B.C. HARC was also able to visit with a number of other manufacturers and suppliers by telephone and at conference meetings including Avista Labs, H Power Corp, Shatz Labs and others. A full list of meetings and contacts developed for this project is presented in Appendix B.

Based upon the above meetings and discussions HARC was able to develop a center concept that provides the essential features needed to allow fuel cell users and system developers to assess the potential for various applications. The basic concept developed is outlined below. Copies of the concept white paper and the overhead presentation are presented in Appendix C and D.

The Center for Fuel Cell Research and Applications

Core Program Overview

Concept:

Core project:

- Industry driven fuel cell applications program operated by HARC
- Driven by six (6) diverse industries
- Evaluate performance of the most current technologies as part of real systems

Ancillary projects:

- Focused projects outside the core program

Cost:

Core project

- $7.2 million total cost for core program

HARC:

- Provides market-driven technology leadership through expertise in critical and focused scientific disciplines
- Offers shared technology resources
- Offers strategic alliances with business, educational and governmental institutions

- 501 c 3 nonprofit research and technology organization
- 15 years experience in managing collaborative research programs
- Neutral and non-competitive
- Provides technical staff, business staff and intellectual property management

Objectives:

- Analyze PEM and other fuel cell technology applications in stationary, mobile and distributed settings
- Evaluate and verify fuel cell system's emissions
- Research environmental and safety aspects
- Establish power quality, reliability and operational characteristics
- Acquire "hands on" maintenance experience with technology
- Evaluate performance of different fuels: H2, CH4, methanol,
- Analyze siting, installation, monitoring, and maintenance for units
- Establish a university linked fellowship program.

Core Program

1-10KW Fuel cells:

- Integrated fuel cell systems in distributed applications
- Develop strategies for peak and dynamic loads

Large Stationary Fuel Cell:

- Demonstrate feasibility of Emission Reduction Credits
- Research benefits of integrated heat recovery
- Integrated fuel cell systems in a commercial setting

Key Benefits to Industry:

- Access to critical evaluation of commercial and pre-commercial fuel cell and related technologies
- Shared costs and risks
- Consortia synergism
- Applications focus
- Experienced research and management
- Offering tax advantages, shared, integrated labs and test bed facilities
- Access to trained staff and students
- Opportunity to influence manufacturers of PEM technology
- Opportunity for future pricing

After a concept/educational white paper was prepared, HARC began to meet with various industry fuel cell end users and system integrators to determine the specific areas of need and preferable ways to organize the center. In this process HARC was also able to meet with energy companies to determine their interests in fuels. Based upon these meetings two mechanisms were developed to involve industry.

In addition to the concept paper, and overhead presentation materials, an educational paper describing the motivation for fuel cells and their potential roles in various industries was created. This paper was used to communicate with businesses and industry and to provide them background for evaluating their own needs in the marketplace. This paper is attached in Appendix E.

Designing the facility

The HARC campus is comprised of approximately 15 acres that house two buildings. There is adequate space with in building two to house the personnel associated with the project including the industry representatives. It has been determined that the amount of space needed for the core project does not warrant a new building on the HARC campus. Instead the test beds for the smaller units will be located within the high bay area of building 2.

The larger stationary units will be housed outside in an area close to building 2. In this way they can be observed in ambient conditions. These larger units require power, water, electricity and other utilities. In addition, these units should be electrically connected to the power load at HARC and with the grid.

HARC is in discussions with Energy Partners for overall assistance on these issues and other issues relating to test bed development, monitoring and instrumentation. HARC will also retain the services of individual fuel cell providers to make sure that their fuel cells are properly sited and instrumented.

HARC is currently developing a detailed planning document addressing safety, scheduling, instrumentation, siting, emissions monitoring, construction and many other issues. This planning document will allow HARC to anticipate and plan for a rapid build up at the official project go ahead.

HARC visited the NASA JSC fuel cell facilities in August of 1998. In reviewing their expertise in operating fuel cells it was decided that HARC and its proposed fuel cell center should work to develop a long-term relationship. To that end a series of discussions have occurred and a draft MOU have been developed.

This document provides for close cooperation between HARC and NASA JSC. Specifically it permits HARC to draw upon their expertise and equipment and for NASA JSC to draw upon HARC's testing and experience with the newer PEM fuel cells. It will provide HARC a resource to evaluate facilities design, as well as safety and instrumentation concerns. The text of the draft document is presented in Appendix F.

Determining Center Budget

The Budget for this project has been determined from the many meetings and discussions with PEM fuel cell vendors and industry representatives. It has been determined that the cost of the facility and equipment, including the test-beds, four 1-10kW PEM fuel cell systems, one 250kW PEM fuel cell system, all necessary personnel and operations of the facility will not exceed $408,000.00 per industry representative per year for a total cost not to exceed $7.2 million total project cost.

Emission Reduction Credits

The Center is currently working with Sterling Consulting Group to establish HARC as a neutral location to "bank" emission information for credit trading purposes. The Sterling Consulting Group is a management-consulting group representing most of the major oil and gas companies as well as many of the big privately held utilities. The concept would include HARC being the repository of emission information and the Sterling Group taking the information and "marketing" the trading of that information. The Center is currently working with Region 6 of the Environmental Protection Agency to further develop the concept.

In Conclusion

The Center for Fuel Cell Research and Applications has completed the conceptual design, has begun contracting for the design of the facility, has determined all the costs for the Center, and is working toward an emission reduction credit program.

Management has met with manufacturers of PEM fuel cells and is in various stages of negotiations with four different manufacturers to provide fuel cell systems to the Center beginning first quarter 1999.

Management has educated a variety of industry energy producers as well as potential end-users of fuel cell technology. The Center has secured 2 out of the 6 industry representatives needed to move forward with the concept of the core project for the Center. Based on the current level of interest, it is anticipated that the additional industry representatives will be identified and educated by the spring of 1999.

Appendix list

- Appendix A: List of Industry and Governmental Contacts
- Appendix B: List of PEM Manufacturers/Meetings and Contacts
- Appendix C: Concept/Educational White Paper for Center for Fuel Cell Research and Applications
- Appendix D: Copies of Educational Overhead Presentation
- Appendix E: Fuel Cell Educational Paper
- Appendix F: Draft agreement with NASA JSC

APPENDIX A

Industry and Governmental Contacts

Environment Protection Agency (Headquarters, Region 6,Region 9)	Texas Alternative Fuels Council
Canadian Consulate	W. Alton Jones Foundation
The Energy Foundation	Environment Now
North American Development Bank	Dynergy
Chevron	Disney Corporation
McDonalds	Texaco
PG&E	Lone Star Gas
Enron	NASA
American Airlines	Marriott Corporation
Southern Company	Fluor Daniel
Motorola	HEB Groceries
City of Houston	Wal-Mart
GSD&M advertising agency	City of Austin
InterConnect Towers	Dell Computers
Coca Cola	Dana Corporation
Los Angeles Department of Water and Power	Mississippi Valley Gas
Skytell	Los Angeles Entertainment Development Corporation
Stewart and Stevenson	Entergy

Appendix B

List of PEM manufacturers /meetings and contacts

1. **July 13, 1998. Enron International**:
   P O Box 1188
   Houston, TX 77251-1188
   713 646-8618

   Tracy Reid. Director of Renewable Energy, Former President of IFC

2. **August 13, 1998. Plug Power**:
   968 Albany Shaker Road,
   Latham New York 12110.
   Tel: 518 782 7700

   John Cerveny: Manager of Economic Development
   Eric White: Manager of Stack Development

3. **August 14, 1998. IFC/ONSI:**
   195 Governors Way.
   South Windsor, Connecticut 06740
   Tel: 860 727 2200

   Douglas Wheat: Marketing Manager
   James Hawkins: Manager National Accounts

4. **October 10, 1998. NASA JSC**
   NASA Road 1
   Houston, Texas
   Tel: 281 483 9056

   Bill Hoffman NASA Engineer
   Michael Le NASA Engineer

5. **October 12, 1998. Energy Partners, Inc.:**
   1501 Northpoint Parkway, Suite 102,
   West Palm Beach, Florida 33407
   Tel: 561 688 0500

   Edward Trlica, President and CEO
   Frano Barbir, Principal Research Engineer

6. **November 20, 1998. Stewart and Stevenson, Inc**
   2707 North Loop West
   Houston, Tx 77008
   Tel: 713 868 7700

   Robert Hargrave, President and CEO
   Garth Bates, Senior Vice President
   Don Wallin, VP for Business Development
   T. Michael Andrews, VP

Appendix C

HOUSTON ADVANCED RESEARCH CENTER

THE CENTER FOR FUEL CELL RESEARCH AND APPLICATIONS

A 'SHARED RESEARCH LABORATORY' TECHNOLOGY APPLICATIONS PROJECT

TABLE OF CONTENTS

CENTER FOR FUEL CELL RESEARCH AND APPLICATIONS

A 'Shared Research Laboratory' technology applications project of the Houston Advanced Research Center

Executive Summary

Within the emerging energy landscape, several significant drivers are shaping and accelerating the demand for distributed, low emission reliable power generation. Among these:

- The deregulation of the energy sector -- specifically that of the electric power industry;
- A diversification of the service offerings of the industry as reflected by the growing requirement for highly reliable and/or high quality power at less than the 1MW level;
- An increasing demand for distributed electric power in currently underserved areas;
- Current and anticipated government air quality mandates calling for dramatic reductions in air pollution emissions in the short to mid-term; and,
- A heightened concern for global climate change in an era of expanding global industrialization.

These trends have resulted in a major increase in activity by government, electric companies, automobile manufacturers and others to invest in research and development for both stationary, portable and transportation fuel cell energy systems.

In response to this interest, the Houston Advanced Research Center (HARC) proposed the creation of the Center for Fuel Cell Research and Applications (the Center) – which would serve to conduct demonstration projects and applied research focused on promising fuel cell technologies.

Initially, the Center's core program will focus on the applications of proton-exchange-membrane (PEM) fuel cells as the value of this technology within the energy industry (stationary, transportation, and others) has been clearly identified. Future activities may, at the direction of the industry participants, incorporate other types of fuel cells technologies as they approach pre-commercialization. Through the Center, industry participants will be provided access to a state-of-the-art laboratory, with field-test, pre-commercial and/or commercial-grade fuel cells as a means to complement and combine with their ongoing research.

THE OPPORTUNITY

Results of the Center's applied research projects will aid in the advancement of fuel cell applications and accelerate fuel cell commercialization by developing a framework and criteria for determining the strategic fit of new technologies in the emerging deregulated energy market. In addition, the project will provide industry participants with:

- A technical basis for developing business strategies;
- A venue for acquiring "hands-on" technical and operations and maintenance experience;
- Technical, operations and infrastructure development data;
- Assessment/verification of total fuel cell system emissions;
- An opportunity to participate in ongoing work/continuing studies, demonstrations and technology verification projects related to fuel cell applications;
- Exclusive use of proprietary data generated in the Center; and
- Selective sharing of non-competitive results with funding participants.

This program will provide an opportunity for participating companies to work through and manage early operational issues while combining resources with other industry participants. By aggregating efforts in this way, the center anticipates these synergies will make the research more cost effective, help to spread the risk, allow for the leveraging of public funds for research, and may provide tangible tax benefits to the participants. Along with the technical and operational work anticipated at the Center, a key objective is the quantification of emissions from the complete fuel cell system, and the resulting value for the energy industry as it seeks ways to comply with clean air standards and benefit from the deployment and operation of clean power generation technologies.

How the Center Will Work

As envisioned, the core program will be funded by up to six diverse industry participants. Each industry participant will appoint a representative to serve on the Center's "Governing Body". The Governing Body will also include the program director of the Center, the technical director, and the Chief Operating Officer of The Houston Advanced Research Center (HARC). The purpose of the Governing body is to set policies concerning the direction and operations of the Center to meet each company's multiple business and technology needs.

Why HARC?

Created in 1982, HARC is a nonprofit university-linked research, development and service institution addressing state-of-the-art technology and policy issues related to energy, the environment, and the needs of society. HARC's participation will add value by drawing upon its experience and technology leadership in:

- Creating value out of strategic alliances with businesses as well as educational and governmental institutions;
- More than 15 years of public and private research [through a 501(c) 3 tax status] in critical disciplines, including energy, the environment, and sustainable development;
- Experience with intellectual property management and technology transfer, including involvement of industry participants staff for on-site/"hands-on" participation in any research;
- Third-party, neutral and objective location ideal for industry-prompted technology and business applications research;
- Existing relationships and ability to tap into the intellectual resources of its network of ten collaborative universities;
- Maintaining a knowledgeable, experienced staff in grant application/ management and contract research administration;
- Offering tax-advantaged, shared, integrated laboratory and test bed facilities, which reduce overall costs; and,
- Offer existing associations with major corporations.

Cost to Participate

The estimated cost for the initial phase of the core program is approximately $7 million with each industry participant contributing approximately $1.2 million -- a cost that will be spread over the three-year term of the core program. Funds for the core program will cover the facility, administration of the project, purchase, installation and operation of the fuel cell systems, monitoring, and information collection, analysis, and dissemination.

In addition to the core program, each industry participant may join, direct or sponsor ancillary programs that study specific uses of fuel cells in specialized settings or in specialized applications. These studies may involve a portion of the entire group or may include outside participants. Costs for each ancillary project will be borne by the respective participant and will be in addition to the core program.

Future Direction

During or after the completion of the core program, new corporations may wish to join the program to pursue demonstration and application projects focusing on "next generation" technology or new related ancillary studies. Any corporation wishing to join after the initial program startup will be charged an entrance fee, plus a proportionate share of overhead and project costs. These dollars will offset the equity contribution made by the founding participants and finance ongoing research that will be available to all industry participants.

This program is believed to represent the first collaborative effort among energy companies and fuel cell developers to generate practical operating data from PEM fuel cells in a variety of applications. By providing industry participants with "hands-on" access to the current state-of-the-art fuel cell technology, this project is expected to ease industry's transition from a regulated marketplace and a purely central generation infrastructure to a deregulated market and an emerging distributed generation paradigm.

Participants will gain invaluable real-world operating experience documenting the economic feasibility of introducing power systems for meeting current and future low- emission and high-efficiency standards. We know of no similar effort being assembled in the United States among national energy companies and fuel cell developers that allows the U.S. energy industry a business incubation opportunity such as this.

INTRODUCTION

The deployment and operation of clean power generation is becoming critical as the energy and transportation sectors seek ways to comply with clean air standards and the nation deregulation of the utility industry. However, for strategic business decisions, considerable analysis is required over the next few years to evaluate the appropriate application and value added from this emerging technology.

To this end the Houston Advanced Research Center (HARC) is proposing a three-year, industry-driven project that centers on the creation of "The Center for Fuel Cell Research and Applications." A collaborative laboratory housed at and managed by HARC, the Center will enable a core group of six diverse participating companies – "industry participants" -- to investigate the economic and operational feasibility of proton-exchange-membrane (PEM) fuel cells in a variety of applications (the 'core' project).

Industry participants, through representation on the "Governing Body" and in conjunction with the HARC project management team, will define the scope of the applied research, cooperatively implement projects, and share research results. While the initial focus will concentrate on PEM fuel cells, future activities, in the form of special projects, may incorporate other types of fuel cells technologies as well.

This document describes the unique benefits of a collaborative approach to PEM applied research, among them a 'shared laboratory concept' leading to cost savings and shared risks as well as access to outstanding research talent and lab facilities. It also describes the benefits provided by implementing the project at HARC, with particular emphasis on HARC's history of managing successful long-term research projects as well as its experience in dealing with industry consortia projects.

The Center in also unique in that it will not duplicate the traditional university role of basic research or that of the fuel cell industry in developing commercial products. Instead, the Center will focus on applications, testing, and demonstration of fuel cell technology. It will take the first of a kind commercial or pre-commercial PEM fuel cell stacks and determine whether they can be used effectively in business situations thereby providing critical information on cost effectiveness, power quality, power reliability, co-generation capabilities and transportation issues, to name a few. The Center will also investigate practical environmental aspects of fuel cells and reformers and the potential impact on air quality and emissions reductions.

The remainder of this document presents the Center's objectives, project organizational structure, project schedule and milestones, project costs, the HARC management organization and project deliverables. Key personnel as well as background on HARC, its research centers and collaborative institutions are also included.

The Center for Fuel Cell Research and Applications

The *Center for Fuel Cell Research and Applications* (the Center) is a new research center at HARC designed to conduct studies on PEM fuel cells and to test their applications in energy and transportation-related disciplines. The Center will coordinate and tailor activities in the application of PEM fuel cells to meet the multiple needs of the energy industry. It seeks to provide key information to the energy industry to aid in the transition to a hydrogen-based economy.

The Center will serve as a resource to industry -- performing studies on the PEM fuel cell in various operating environments. Industry participants will be invited to participate in studies focusing on large- and small-scale applications for stationary use of fuel cells technology. Initially, the Center will conduct its studies on one, 250kW PEM fuel cell, as well as several smaller, low-powered fuel cells.

The Center will provide opportunities for basic and applied research and will foster technical, intellectual and financial collaboration among organizations and companies for the purpose of advancing the integration of fuel cells into the energy mix. The Center will be a platform for end-users of fuel cell technology to participate in demonstrations and validation for a wide array of products. Demonstrations will include the integration of fuel cells into the power grid, performance and reliability testing, power quality testing, operations training, verification of emissions data, demonstration of the value of Emission Reduction Credits, and the identification and potential resolution of problems associated with fuel cell technology. Industry participants -- companies choosing to participate in the programs of the Center -- will guide the program and have advance access to critical information on the identification and management of early operational and maintenance issues surrounding the technology.

The Center is also exploring, in conjunction with homebuilders in The Woodlands, Texas, the option of incorporating one of the smaller fuel cells into a 2,000 square-foot single family dwelling. The primary focus will be on reliability, emissions testing, power quality, design modifications, installation issues, maintenance, and consumer acceptance in a residential setting. Similar demonstrations within the automotive industry will be explored, expanding to include the public transportation system located within the Woodlands.

The Center facility will consist of administrative office space and "high-bay" laboratory space and will be designed so that experiments and demonstrations may be conducted either on a group or proprietary basis. Participants will be provided with a furnished, secured private office and will have access to common space.

Key Objectives

Key objectives of the Center include the following:

- To analyze the operating characteristics of PEM and other fuel cell technologies in stationary and mobile conditions in commercial, industrial and residential settings.
- To perform research on the total fuel cell system's by-products and how they can be integrated into the energy mix (*i.e.*, heat, carbon dioxide).
- To analyze the operating characteristics of the total PEM cell system on a variety of fuels.
- To perform research on the environmental and safety aspects of fuel cell operations.
- To share program results with industry participants.
- To disseminate non-proprietary program information within the scientific community.
- To establish a fellowship program for graduate student participation and training in fuel cell technology.
- To capitalize on opportunities for industry participant's public relation benefits.

Initial Projects

The core program will focus on the following:

<u>Using <10kW fuel cells:</u>

- Analyze the full cycle of emissions data and their impact on air quality using various types of fuels.
- Monitor and analyze the emissions and air quality performance in a residential setting where a fuel cell will be the primary source of power in a typical 2,000 square foot single family dwelling.
- Determine cost effectiveness, reliability and practicality of integrating fuel cell technology into residential applications.
- Analyze siting, installation, commissioning, monitoring and maintenance requirements for localized applications (*i.e.*, gated communities, premium power applications, uninterruptable power systems, etc.).
- Research and demonstrate the efficiency factor using different fuels in a variety of distributed generation applications.

<u>Using 250kW fuel cells:</u>

- Determine issues associated with the integration of large fuel cells into the power grid.

- Research and analyze the impact of air quality emissions from fuel cells in a city that suffers from air quality problems.
- Demonstrate the feasibility of Emission Reduction Credits for fuel cell technology.
- Monitor the operations and on-going maintenanc as well as offer proof-of-cost viability through the analysis of life cycle costing of the fuel cell units in various commercial environments.
- Determine site-specific siting, commissioning, and training criteria of the fuel cell units in ambient conditions.
- Monitor the performance, reliability and power quality produced by a large-scale fuel cell.
- Research the utilization of the stationary power plant's reformer to produce hydrogen for use in a vehicle refueling application.
- Research the development of an integrated heat recovery unit to capture the economic opportunities available from the by-production of heat or steam.
- Conduct research on other projects as recommended by the Governing Body.

INDUSTRY PARTICIPATION

To ensure that the key objectives of the Core Project are met, a Governing Body will be created to define and coordinate the research priorities for the core project and any related ancillary projects. The Governing Body will consist of one representative from each of the industry participants, the director of the Center, the Center's technical director, and the Chief Operating Officer of HARC.

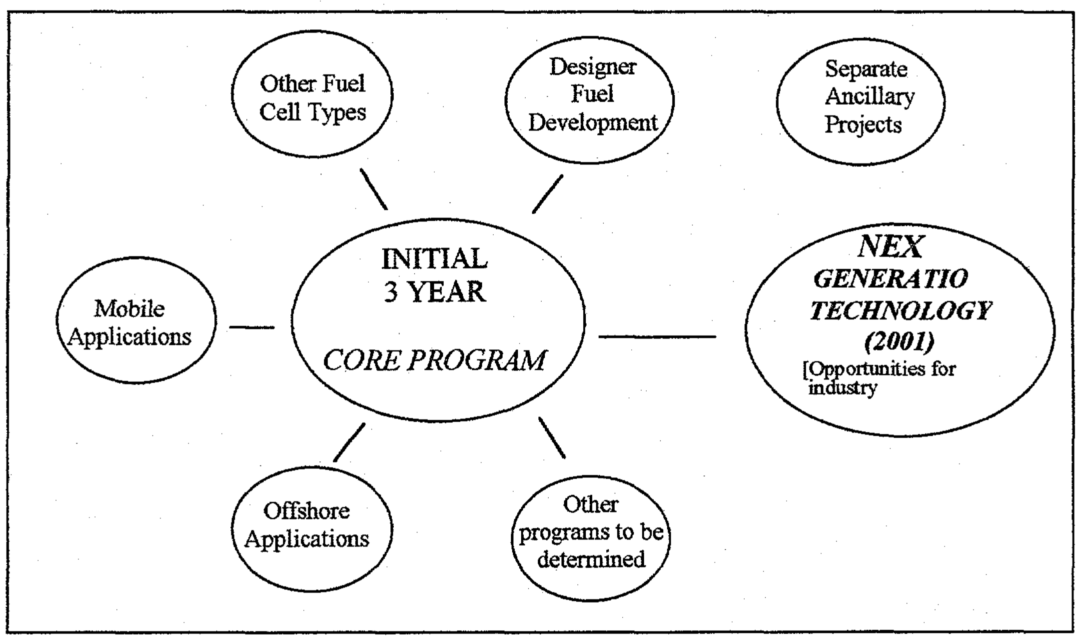
The Governing Body will adopt formal bylaws defining operations of the Core Project. The Governing Body will determine the research and development activities of the Core Project, the use of all project property and related personnel, exploitation of any resulting intellectual property resulting from the Core Project, and resolution of any disputes among industry participants. All decisions of the Governing Body shall be determined by a two-thirds ($2/3^{rd}$) vote of all members. The Governing Body shall meet at least quarterly.

The core project has been designed as a flexible resource for industry. It provides the infrastructure necessary to build an ongoing research program. In addition to the core project, each industry participant may join, direct or sponsor ancillary projects to explore specific uses of fuel cells in specialized settings or applications. The studies may involve a portion of the entire group or may include outside participants. Costs for each ancillary project will be borne by the respective participants and will be in addition to the core project.

One such study being contemplated is to test a second 250kW fuel cell. This unit could either be the next generation PEM commercial fuel cell developed, or could include a completely different type of technology defined by the needs of the Center's industry participants.

After the completion of the core project, new corporations may wish to join the center in order to participate in the demonstration and application of "next generation" technology or in new ancillary studies. Any new corporation wishing to join, create or establish a "related" ancillary project after the initial core project startup will be charged an entrance fee, plus a proportionate share of overhead and future fuel cell demonstrations. These dollars will help to reduce future costs of the Center.

A model illustrating the relationship between the core program and other related programs is outlined below:



PROGRAM IMPLEMENTATION/MILESTONES

The following timeline has been established for implementation of the fuel cell research program:

July 1998 – January 1999

- Solicitation of industry participants continues
- Industry Participation Agreements constructed
- Arrange financing for equipment, fuel cells and facility construction

January 1999 – July 1999

- Facility design and construction
- Research program designed

1999: Q3 – Q4

- Receive and install first smaller fuel cell unit (committed from Ballard)
- Research program implemented

2000: Q1 - Q4

- Receive and install one 250kW natural gas field test unit (committed from Ballard – Q3)
- Receive and install three additional smaller fuel cell units (manufacturers to be identified)
- Research program implemented

COSTS ASSOCIATED WITH THE CORE PROGRAM

Based on the above schedule, the Core Program will be a three-year program. The Center will acquire four <10kW PEM fuel cells beginning in 1999 and one 250kW PEM fuel cell in 2000. It will also serve as the basis for future research modules. The proposed budget is as follows:

Annual Personnel Costs:	
Program Director	$100,000
Technical Director (p/t)	62,500
Safety Advisor (q/t)	20,000
Testing Engineer (f/t)	90,000
Facility/Technical Engineer (p/t)	25,000
Administrative Assistant	35,000
Fellowship Program	50,000
Subtotal	**$382,500**
Benefits (36%)[1]	137,700
Subtotal	**$520,200**
HARC Overhead (30%)[2]	156,060
Total	**$ 676,260**

Budget

	1999	*2000*	*2001*
Annual Personnel Costs	$676,260	$676,260	$676,260
Operational Expenses			
Natural Gas	8,000	15,000	21,000
Utilities	9,000	10,000	10,000
Travel/Conferences	30,000	25,000	20,000
Telephone/Communications	12,000	12,000	12,000
Special Security	15,000	15,000	15,000
Postage	1,500	1,500	1,500
Supplies/Miscellaneous	4,000	10,400	15,000
Testing Expenses [4]	30,000	100,000	130,000
Total - Operational Expenses	**$ 109,500**	**$188,900**	**$224,500**
Personnel	676,260	676,260	676,260
Operational Expenses	109,500	188,900	224,500
Amortization of Capital Expenses[3,4]	1,585,300	1,585,300	1,585,300
Total Expenses Per Year	**$2,371,060**	**$2,450,460**	**$2,536,060**
Required Industry Participant Contribution[5]	$408,750	$408,750	$408,750

[1] HARC's share of social security, unemployment taxes and employee benefits
[2] Includes property insurance, general HARC support, accounting, general utilities, personnel services, general security and program oversight
[3] 3-year amortization at 7.2%
[4] One 250 kW fuel cell, 4 <10kW fuel cells
[5] Based on six industry participant

The proposed budget will cover the cost of the core project, including the cost of the facility; administration of the program; acquisition of the equipment, integration of the cells and information collection, analysis, a university-linked intern program, and dissemination of the research.

To become an initial Center participant, each Industry participant will enter into a Industry Participation Agreement that provides for each entity making the annual payments for the duration of the core program that is anticipated to be three years. This time period has been established by fuel cell availability and delivery schedule proposed by the manufacturer.

Potential Tax Credits

The participants financial participation may be eligible for federal research tax credits and/or charitable contributions. On October 21, 1998, the United States Congress extended the tax credit for business research and development that expired on July 1, 1998. Depending on the tax position of the individual participant, the proposed tax credits will have the effect of reducing the cost of participation to forty cents on the dollar.

EXAMPLE

Assumptions:

- A corporation fully qualifying for credits
- Incremental tax credit is renewed
- Tax rate of 35%
- Annual expenditures and savings

Industry Participation for Core Program	$408,750
less: 20% tax credit	(81,750)
20% basic university research payments	(81,750)
	245,250
Tax Savings with Expense Deduction	(85,375)
	$159,875

or a net cost of $ 0.40 per dollar

Each industry participant is advised to consult with their legal counsel and accounting firm regarding possible tax benefits associated with participation in this program.

Organizational Structure

Initially, a full-time director, a technical director, a testing engineer, a quarter-time safety advisor, and a full-time administrative assistant will staff the Center. Additional technical staffing requirements will be addressed on an as-needed basis, by calling on fuel cell expertise from manufacturer and collaborative universities.

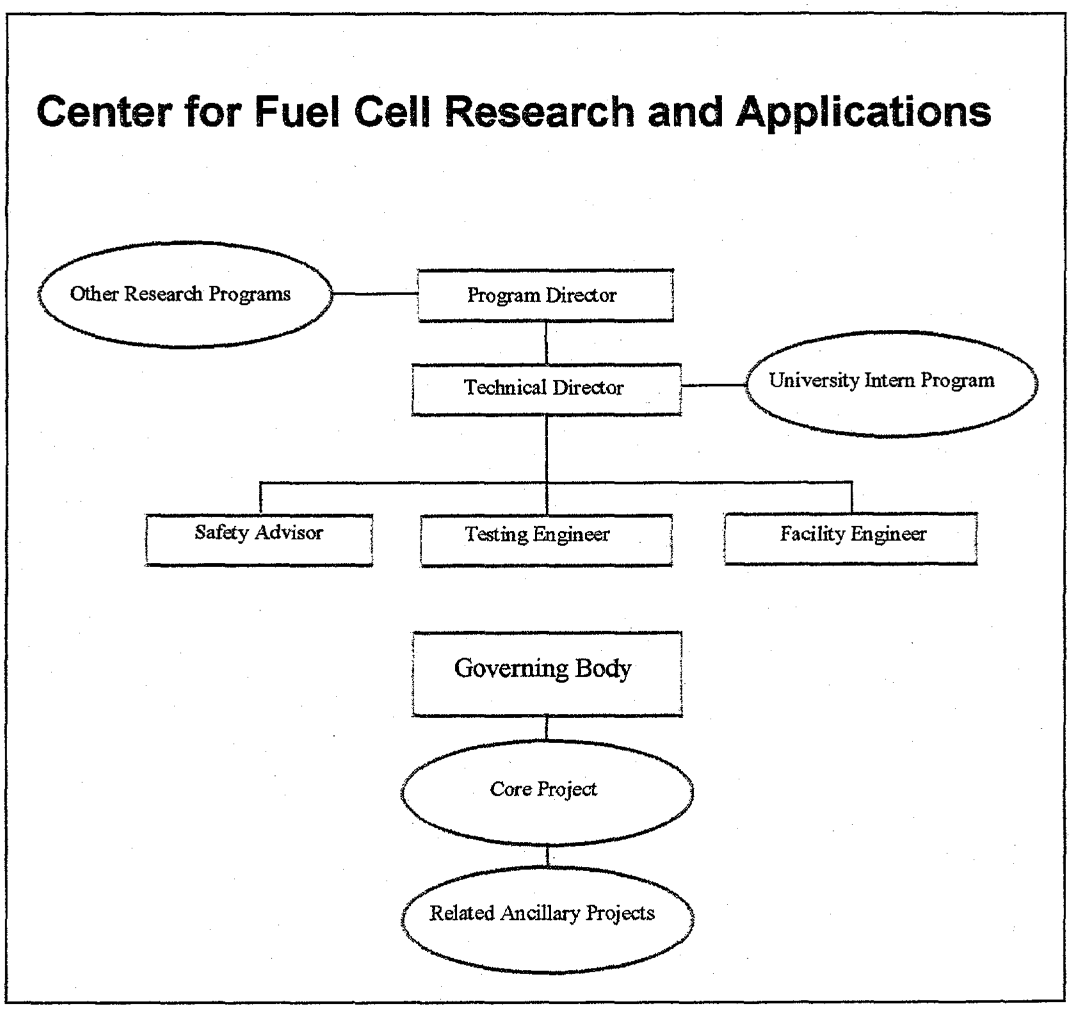
As director, Patrice "Pete" Parsons will serve on the Governing Body and be responsible for and direct the daily operations of the Center. Ms. Parsons will manage the research programs conducted at the Center and will implement the agenda established by the Governing Body. She will oversee the establishment of the research facility and the commissioning of the fuel cells. In addition, Ms. Parsons will work closely with members of industry and, as directed, will facilitate relationships with federal agencies whose interests align with the Center. Ms. Parsons will also ensure that measures are being taken to comply with occupational and environmental guidelines.

As technical director, Dr. David Norton will integrate activities of the Center with HARC programs and those of HARC's collaborating institutions. Dr. Norton will serve on the Governing Body, and will assist in implementing their technical recommendations. Dr. Norton will establish the fellowship program and will coordinate the activities of the visiting scientists and graduate students.

As quarter-time safety advisor, Phillipe Tissot will oversee compliance with health and safety requirements and will ensure compliance with federal, state and local regulations.

The testing engineer will be responsible for the daily operations of the fuel cells and ancillary equipment in the Center. He or she will also have primary responsibility for maintenance and repair of the equipment.

The part-time facility/technical engineer will maintain the facility. It is projected that the majority of his services will be needed during the facility start-up phase and commissioning of the fuel cells.



Deliverables

The Center for Fuel Cell Research and Applications management team will provide the following set of deliverables to the industry participants:

- Quarterly management reports,
- Databases developed from the research,
- Monthly tracking and reporting on research,
- Semi-annual review meeting,
- Annual financial report and audit, and
- Any appropriate "flash" reports.

For more information contact:

Pete Parsons, Center Program Director, at 512/380-0283, 281-363-7929,
Email pparsons@harc.edu; *or*

Dan Davis, Chief Operating Officer of HARC, at 281-363-7912,
Email dgd@harc.edu

RESUMES OF KEY PERSONNEL

4205 Bradwood
Austin, Texas 78722
512-380-0283
512-380-0296 (fax)
pparsons@harc.edu
The Woodlands
281-363-7929
281-363-7935(fax)

Patrice Parsons

BACKGROUND SUMMARY

Extensive experience in energy and environmental policy planning, program development and implementation. Recruited, trained, and supervised staff. Created and implemented marketing strategies; developed and monitored budgets; developed and coordinated lobbying strategies for coalitions of diverse groups of constituents.

ACCOMPLISHMENTS

May 1997 – June 1998

MANAGEMENT

<u>Texas General Land Office</u>

Associate Deputy Land Commissioner for Energy Resources

Department Head of a seventy six member staff responsible for oil, gas and mineral lease sales totaling $198 million dollars annually. Managed royalty payments lease audits, in-kind gas program and alternative fuel programs for the State of Texas. Reorganized department and established team to recover $6 million in unresolved royalty payments. Served as the Commissioner's spokesperson on climate change issues, renewable energy, and the U.S. Clean Air Act Advisory Committee.

February 1996 – April 1997

Director, Alternative Fuels Division

Directed staff of seven charged with the development and promotion of alternative fuel vehicle and infrastructure programs in Texas. Coordinated all governmental relations for the division.

- Created a statewide strategic plan for the deployment of alternative fuels.

- Developed initiatives and secured funding on projects for airport operations, bi-national freight shipping, "market-pull" consolidated purchasing cooperatives, long distance trade corridors and mobile source emission reduction credits, which have evolved into national models for the U.S. Department of Energy.
- Received national recognition for creating a taxi program in New York City that created the largest fleet of light-duty natural gas vehicles in the U.S.
- Established Department of Energy's Clean Cities coalitions in Houston, Dallas/Fort Worth, Austin, Corpus Christi, El Paso, San Antonio and Laredo and secured funding for staffing for these organizations.
- Organized the sixth and seventh annual International Alternative Fuels Conferences and Trade Exhibitions. Coordinated all governmental relations for the division.

February 1995 – January 1996

Special Assistant to the Commissioner

Directed the Texas Sustainable Energy Development Council, which was created to develop a strategic plan to ensure the optimum utilization of Texas' renewable and efficiency resource base. This project included identification of the state's available renewable and energy efficiency resource base and development of a model indicating how these resources interact with each other and with existing energy production and consumption.

February 1993 – January 1995

State of Texas, State Energy Conservation Office

Director

Directed a department of thirty responsible for all state energy conservation programs, including thirty-three different program areas. Responsible for managing approximately $200 million of Petroleum Violation Escrow (PVE) funds.

- Overhauled the State Energy Conservation Office's accounting system to dramatically improve system accuracy and accountability and to reconcile with U.S. Department of Energy figures.

- Served as state representative to the National Association of State Energy Officials. Coordinated all governmental relations for the department.

May 1991 – January 1993

General Services Commission

Director of Environmental Programs

Directed a team of four employees responsible for the implementation of environmental programs throughout the agency's operations. Projects included revision of the State's Architectural and Engineering Guidelines to incorporate "Green Building" guidelines, initiation of the state's recycling program, modification of state purchasing policies to include recycled and environmental products.

- Prepared and secured passage of legislation to strengthen the state's Solar and State Structures statute relating to renewable building practices within state office building construction.
- Organized the agency's annual recycling conference and conducted ten seminars on Sustainable Building Practices for all state agency and university architects.

1985 - 1991

PRIVATE SECTOR EXPERIENCE

Political Consulting

Developed and managed direct-mail programs and phone bank operations for various successful grassroots lobbying efforts.

- Organized and led the Texas Growth Fund campaign (Constitutional Amendment) from its inception and coordinated all administrative activities.
- Organized and coordinated twenty counties for a Texas Senatorial campaign.
- Managed several large political fundraising efforts.
- Organized, coordinated and successfully secured passage of a $14 million general bond authorization for schools in Gillespie County.

1978 - 1984

Commercial Real Estate

- Managed several commercial office buildings in Austin totaling more than 1.5 million square feet. Responsibilities included marketing, design and construction oversight and property management duties.
- Expertise in marketing commercial properties as a commercial real estate broker.

EDUCATION

University of Texas at Austin, B.S., Education, Honors
1976

VOLUNTEER/
COMMUNITY

Precinct Chair, Hays County, Texas
AIDS Services of Austin - Board of Directors
Sharir Dance Company - Board of Directors
The Center for Battered Women - Board of Directors
The Austin Children's Museum- Board of Directors
Austin Drug Abuse Program - Board of Directors
Austin Chamber of Commerce - President's Council
Texas Rate Payers to Save Energy- Board of Directors

Houston Advanced Research Center
The Woodlands, Texas 77381
(H) 281-292-3875
(W) 281-363-7973
(F) 281-363-7914
norton@harc.edu

David J. Norton, Ph.D., P.E..

BACKGROUND SUMMARY

Experience in learning, research and technology transfer. Understand people who create technology and the process of forging economic outcomes from R&D. Created and led research and technology organizations. Developed strategies for workforce development and learning for knowledge based organizations.

ACCOMPLISHMENTS

1986 Present

<u>Houston Advanced Research Center</u>

Director of Space Technology and Research Center:

Created center to develop and use space technology for the civil, military, and commercial space applications.

- Created center to work in the national space program
- Developed classified microwave imaging program

Vice President for Research

Key role in the creation of a university linked, nonprofit research and technology transfer organization. Developed and managed the $15 million research budget. Provided strategic and financial oversight for 8 research divisions.

- Managed the research program at HARC
- Converted HARC to 50% industrial support
- Liaison to Washington DC and state capital

- Budget, recruiting, management, board of director's meetings

Director of Laboratory Programs

Developed new programs in the role of learning and technology in the work force of tomorrow. Organized and managed new research centers around emerging technologies

- Led program development in emerging technologies: DNA, brain physics
- Created and led the Telemedicine Technology Laboratory
- Created and led a Distance Learning Laboratory

1970-1986

Texas A&M University

Assistant, Associate, Full Professor

Aerospace Engineering Department. Teaching, research and graduate students. Ten years of continuous research for NASA on space shuttle aerodynamics and propulsion. Achieved tenure and full professor.

- NASA research on Space Shuttle heat tiles
- Environmental Aerodynamics and Wind Engineering
- Created 4 new engineering courses

Assistant Director for Research

Texas Engineering Experiment Station

Managed and coordinated the research of 25 divisions. Represented institution at state capital. Created the model for the national Space Grant program.

- Managed 25 research divisions
- Created divisions at other universities
- Conceptualized and created Space Grant concept for TAMU

1968-1970

U.S. Army

- Captain, U. S. Army Ordnance Corps: Commissioned at Texas A&M University. Served 8 years in reserves and active duty.

- Jet Propulsion Laboratory active duty 2-year assignment. Advanced Propulsion Division

EDUCATION

B.S. mechanical engineering, Texas A&M University. 1963
M.S. in mechanical engineering, Texas A&M University. 1963
Ph.D. in mechanical engineering, Purdue University. 1968

AFFILIATIONS

B.S. mechanical engineering, Texas A&M University. 1963
American Society of Mechanical Engineers
American Institute of Aeronautics and Astronautics
Tau Beta Pi
Phi Kappa Phi
Sigma Chi

CLUBS

The Cosmos Club, Washington D.C.

PROFESSIONAL REGISTRATION

Registered Professional Engineer

HONORS/AWARDS

Named Purdue University Outstanding Mechanical Engineering graduate in 1995

Named Brockett Professor of Aerospace Engineering at Texas A&M University

Served on 1995 and 1998 Oak Ridge National Laboratory review team for the Instrument and Controls Division

CIVIC ACTIVITIES

Board of the Montgomery County Library system

Board of the Education Tomorrow Alliance

Houston Advanced Research Center
4800 Research Forest Drive
The Woodlands, TX 77381
281-364-4020
ptissot@harc.edu

Philippe E. Tissot, Ph.D.

ACCOMPLISHMENTS

May 1995 to Present

<u>Houston Advanced Research Center</u>

Institutional Radiation Safety Officer (IRSO)

Dr. Tissot is in charge of the supervision of all activities involving the use of radiation sources or radiation producing machines. He wrote and updates as needed HARC Radiation Safety Policies and regulations and supervises the operation of the individual laboratories radiation safety programs. Dr. Tissot is also the Radiation safety officer for the Technology Development Laboratory.

Member of HARC Safety Council

As a member of HARC's safety council, Dr. Tissot reviews all safety aspects of HARC operations and advises in his areas of expertise such as radiation safety and other engineering disciplines.

Research Scientist at HARC's Technology Development Laboratory (TDL)

As a research scientist at TDL of the Houston Advanced Research Center, Dr. Tissot leads technology transfer and Research and Development projects. Recent projects include:

- Development and optimization of a delivery process for the treatment of lumber by vacuum impregnation based on a proprietary process developed by a South African Research Center.
- Development of a silicide characterization technique based on Rutherford Backscattering Spectrometry for a Semiconductor company.
- Development of a method to measure the near surface characteristics of processed 300 mm silicon wafers non-destructively.

- Development and testing of a cooling system for High Purity Germanium (HPGe) detector based on the first commercial version of a pulse tube cryocooler.
- Study and simulations of the implementation of Prompt Gamma Neutron Activation Analysis (PGNAA) to the problems of soil contamination screening (NASA Marshall), and mines and buried ordnance detection.
- Development and surface testing of a downhole High Purity Germanium (HPGe) detection system for the oil logging industry for a Houston based oil company.
- Study of cooling system for SQUID based detection systems.
- Study of alternate gamma ray detectors for nuclear logging of oil wells and in particular high Z semiconductor detectors.

August 1994 - May 1995

Instructional Materials Specialist at the Electronics Training Division (ETD) of the Texas Engineering Extension services (TEEX). Principal investigator in the development of a course on the processes and fundamentals of silicon materials fabrication for Texas Instruments.

1988 - 1994

Texas A&M University. Research assistant responsible for operating, maintaining and modifying a 200 keV Cockroft Walton ion beam accelerator, including the vacuum systems, the ion gun, the ion optics and the vacuum chamber and its apparatus.

1987

Innovi SA Le Locle (Switzerland). Scientific evaluation for venture capitalism, primary participant in the conception and programming of the analytical accounting of the company.

EDUCATION

Ph.D. in Nuclear Engineering, Texas A&M University, May, 1994. *Dissertation*: Fabrication of <100> Germanium Silicon layers by heated ion implantation and study of pre- and post-anneal characteristics by channeling and RBS (Rutherford Backscattering Spectrometry).

Diploma Engineering Physics, Swiss Federal Institute of Technology at Lausanne, Switzerland, January, 1987. *Thesis*: Analysis of the degradation of MoS_2 protective coatings when exposed to humidity using AES (Auger Electron Spectroscopy) and XPS (X-ray Electron Spectroscopy).

QUALIFICATIONS/ AFFILIATIONS

Certified Radiological Safety Officer: completed the 40 hour radiological safety officer course at the Texas A&M University Office of Radiological Safety, April 9, 1996.

Familiar with Nuclear Engineering simulations using the Monte-Carlo Code MCNP (completed the 40-hour class, introduction to MCNP, at Los Alamos National Laboratory).

Member of Alpha Nu Sigma honor society, the American Nuclear Society, the American Physical Society, and the Materials Research Society.

PUBLICATIONS/ PRESENTATIONS

John Colvin, Tom Mann, Scott Peck, Philippe Tissot*, John Ziegler, "A Second Generation MicroSmes" Superconductor Industry, Winter 1997-1998 Issue. (* Author of the article)

P.E. Tissot, J.C. McCoy & R.R. Hart, "Medium Energy implantation of germanium into heated <100> Silicon", Applied Physics Letters 66-8 (1995) 979-981.

P.E. Tissot & R.R Hart, "Ion Beam Heating of Thin Silicon Membranes," Nuclear Instruments and Methods B79 (1993) 796-799.

P.E. Tissot, L. Crowe, J. Colvin, T.L. Mann, and A. Guerra, "Design and Testing of a Pulsed Tube Based Cooling System for High Purity Germanium Detectors", submitted for publication at the 1997 Cryogenic Engineering Conference.

J. McCoy, P.E. Tissot & R.R Hart, "High Fluence Implantation of Ge into Heated <111> Silicon," poster presentation at the 12th international conference on the applications of accelerators in research and industry, Denton, Texas, 1994.

P.E. Tissot, J.C. McCoy & R.R Hart, "Germanium Silicon Layers Produced by Implantation of Silicon <100> Substrates," oral presentation at the fall 1993 meeting of the APS/AAPT (Texas section) in College Station, Texas (This presentation received an award for outstanding research paper from the APS industrial section sponsorship fund).

Participation (principal investigator) to the design, research, and text development of the course "Silicon Manufacturing Overview", Texas Engineering Extension Service, Electronics Training Division, 1997, Texas A&M University System, College Station, TX 77843-8000 (Currently teaching this class as a part-time instructor for TEEX-ETD).

Participation (principal investigator during the first phase of the development) in the design, research, and text development of the four volume course "Silicon Materials Fabrication," Texas Engineering Extension Service, Electronics Training Division, 1996, Texas A&M University System, College Station, Texas 77843-8000 (Currently teaching this class as a part-time instructor for TEEX-ETD).

APPENDIX

Fuel Cell Background
HARC Background
HARC Centers & Collaborative Institutions

Fuel Cell Background

Fuel cells date to 1839, but it wasn't until the early 1960s that NASA began using the technology in its space program. While fuel cells helped put a man on the moon, they have, until recently, been considered too costly for most down-to-earth applications.

Over the past few years, however, engineers have begun designing fuel cells with more practical applications. Envisioned are quiet, decentralized electric plants ranging from those small enough to power a car (and perhaps, at night, a home) to fuel cells large enough to power a small town of 15,000 people. Public mandates for reduced carbon consumption have driven the development of fuel cells and other environmentally benign energy sources.

Compared with the internal-combustion engine (ICE), the fuel cell engine is a simple device. Fuel cells are electrochemical devices that are clean, quiet and efficient; they operate continuously as long as fuel is supplied. Fuel cells have no moving parts; therefore, they are extremely reliable and have long operating lives. Fuel cell systems can use any of a number of fuels such as natural gas, methanol, ethanol, and hydrogen and the fuel cell process is two to three times more efficient than that of an ICE. In addition, the only by-products of the fuel cell itself, are electricity, water, and a moderate amount of heat.

After decades of unfulfilled promise, fuel cell momentum is now so great that its emergence as a dominant technology appears inevitable.

While the shift to a mature "hydrogen economy" is likely to require another 50 to 100 years, the impact of fuel cell technology should be felt long before that. The August 1, 1998 issue of the *Economist*, for example, reports that Zevco, a small Anglo Belgian firm, has "just launched the world's first taxi to be powered by smooth, silent fuel cells." Over the next decade, technologies are likely to emerge that are both more efficient and environmentally friendly than their predecessors. The use of fossil fuels to power fuel cells will be transitional, leading to an era in which hydrogen is extracted from sustainable energy sources. Implications of such a development are far reaching and include a drastic decline in air pollution, oil spills, acid rain, and greenhouse emissions. A demonstration of this potential will have significant implications as power companies seek ways to comply with clean air standards.

There are currently five types of fuel cells: the alkali cell, the molten-carbonate cell, the solid-oxide cell, the phosphoric-acid cell, and the proton exchange membrane (PEM) cell – with the latter two showing the most promise for practical use. All five fuel cell types use catalysts to speed up the chemical reaction and many also rely on high temperatures. The most expensive fuel cell is the alkali cell used in space vehicles. It enjoys the highest ratio of power to weight, but it needs expensive metals, such as platinum and gold, to coat its electrodes. In addition, its electrolyte is made of potassium hydroxide, which tends to react with CO_2 in the air to form potassium carbonate. That means it needs a supply of pure oxygen, which adds even more to the expense of the technology. Molten-carbonate and solid-oxide cells operate at 600°C and 1,000°C respectively, therefore, do not need expensive hydrogen as fuel. Instead, they can use methane, which is available in natural gas. Both types, however, have their drawbacks. The solid-oxide fuel cell requires sophisticated ceramics for its electrodes and an exotic mixed oxide as an electrolyte. Similarly, the electrolyte in a molten-carbonate cell is so hostile its electrodes tend to "give up the ghost" regardless of their composition.

The remaining two cells offer the best promise for commercialization. The phosphoric-acid cell, currently in commercial production, is favored to replace behemoth gigawatt-producing power stations and the proton exchange cell (PEM), which has numerous applications including both large and small-scale stationary applications, portable applications and/or mobile applications.

While the PEM cell operates at a relatively low temperature – around 80°C – until recently it required immense quantities of expensive platinum as a catalyst. However, in 1993, through a partnership with a British company, Ballard Generation Systems found a way to reduce the platinum, thereby making the PEM fuel cell more affordable.

PEM fuel cell technology is ideally suited to multiple applications based on the needs and requirements of the customer. This range of applications includes stationary (500W to 1MW), portable (<500W), transportation, marine, and many others. PEM technology is considered the most commercially viable technology for units rated at 250kW and below. In addition, it is expected that PEM technology will become more affordable because it has components that are plastic and recyclable, and operates at a lower temperature resulting in less degradation to the fuel stack components. Because PEM technology is scalable and versatile, it is uniquely suited for customized solutions.

How the Ballard PEM fuel cell works

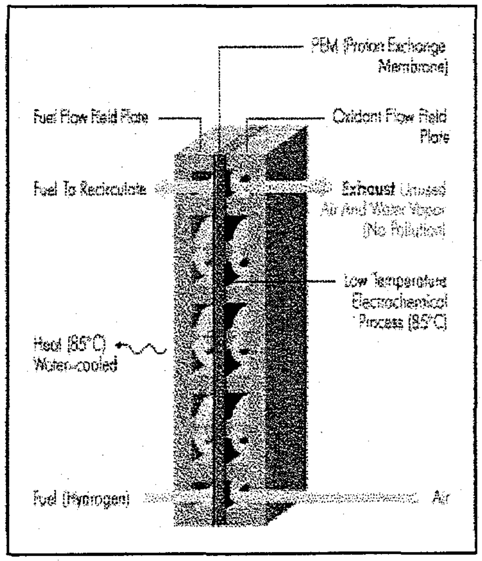


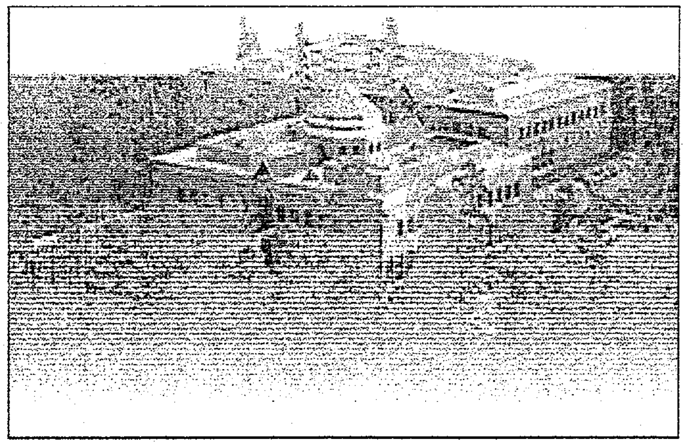
Illustration courtesy of Ballard Generation Systems

Additionally, the versatility of PEM technology may make it the ideal choice for businesses wishing to position themselves within the emerging energy environment. Companies such as Ballard, Daimler-Benz, Honda, Toyota, Ford, Fuji, Sanyo, Mitsubishi, Toshiba, Hitachi, Siemens, DeNora, International Fuel Cells (IFC), H-Power, Chrysler, and Plug Power are looking at PEM fuel cells in a variety of applications including automotive.

The Center seeks to provide its industry participants with the capability to determine the suitability of PEM technology for stationary and transportation applications. Stack technology, systems integration, research and development strengths, financial partnerships, manufacturing and commercialization capabilities will be considered in the program.

HARC BACKGROUND

Founded in 1982, HARC is a non-profit, university-linked organization focusing on market-driven scientific research and applied technology development. Specialists from education, industry, and government come to HARC to conduct research, develop new models for the efficient transfer of technological developments to the marketplace, and increase awareness in the social and policy implications of advances in science and technology.



As a market-based research institution, HARC is supported by both the public and private sectors. Energy and the environment represent HARC's major research focus. The value of HARC's work is shared though conferences, workshops, publications, and the development and commercialization of new technologies. HARC researchers work closely with colleagues at 10 collaborative institutions.

Since 1985, HARC has performed more than $135 million in research and currently attracts more than $13 million annually in industry and government support for its programs. Its intellectual property history includes 41 U.S. patent applications filed, 27 patents issued and 20 patents or patent application transfers. Eight organizations and companies have spun out of HARC's research and some 150 companies benefit annually from its research. According to Economist Ray Perryman, HARC generates $37.7 million annually in total expenditures within the Greater Houston economy.

Located 27 miles north of Houston in an area of The Woodlands known as the Research Forest, the HARC campus is nestled on 100 acres of east Texas forest, with a staff of over 100 scientists, specialists and support personnel.

Center for Global Studies (CGS)

CGS assists private industry and the public sector in making sustainability work for them. Center activities include studies, training, conferences, workshops, and briefings on various aspects of sustainability. Topics include water resources, energy policy, air quality, population growth, regional development, corporate strategies, and governmental planning. Expertise includes environmental and science policy, corporate environmental policy, regional and urban planning, economic analysis, and decision process management.

Geotechnology Research Institute (GTRI)

GTRI participates with industry and government to develop leading edge technologies for oil and gas exploration and production. Facilities include a Geochemistry Laboratory (donated by Texaco), a Rock Physics Laboratory (donated by Unocal with additional support from ARCO, Exxon and Texaco), and an NEC SX-4 supercomputer. Expertise includes geochemistry, seismology and rock physics.

Environmental Information Systems Laboratory (EISL)

EISL uses advanced computer technologies to integrate, visualize, and analyze spatial data for a variety of earth resource related projects – from mapping hazardous waste sites to developing sensors for environmental monitoring. EISL provides three critical areas of expertise: sensor design to detect targets, software development to integrate information systems technologies, and environmental/earth science applications.

Astroparticle Physics Group

This group is dedicated to cracking the cosmic code from two directions. First, a top-down approach that explores the origin of space and time, block hole dynamics, and the unification of quantum mechanics and gravity at the most fundamental level. The second, a bottom-up approach, involves building and studying supersymmetric unified models of elementary particle physics, focusing on their experimental and cosmological implications.

Technology Development Laboratory (TDL)

Engineers at TDL are developing a micro-SMES working prototype for stabilizing electricity. TDL also conducts research and development and provides testing services in the areas of cryogenics and superconductor technologies. Other studies involve superconducting magnetic energy storage systems, associated vacuum and electronics, cryogenic material and component testing, electric power transmission system analysis, and related engineering projects.

Fondren Telemedicine Technology Laboratory (FTTL)

Members of this laboratory conduct assessment and development projects to test and demonstrate new technologies for medical telecommunications and health care delivery systems. Expertise includes physician and clinical productivity tools, PC-based interactive desktop video, technology assessments and audits, and home health care technologies.

DNA Technology Laboratory (DNA)

The DNA Laboratory is a key player in the emerging genosensor field, developing DNA chips that can quickly analyze genetic alterations. Genosensors are expected to create a host of benefits for the diagnosis of cancer as well as genetic and infectious diseases. Testing is currently in progress on a DNA chip dedicated to the detection of antibiotic-resistant strains of mycobacterium tuberculosis. Work also continues on mutation detection of retinoblastoma, a childhood cancer of the eye, and on identifying alterations in breast cancer susceptibility genes. Laboratory researchers are also investigating a novel strategy for the rapid typing of human leukocyte antigens (HLA) to match donors and recipients of bone marrow transplants.

HARC COLLABORATIVE INSITUTIONS

Baylor College of Medicine
Duke University
Insituto Tecnologico y de Estudios Superiores de Monterrey (ITESM)
Louisiana State University
Rice University
Sam Houston State University
Texas A&M University
The University of Texas at Austin
The University of Texas Medical Branch at Galveston
University of Houston

References

"At Last, the Fuel Cell," The Economist, October 25, 1997, pp. 89-92.

"Dawn of the Hydrogen Age," Jacques Leslie, Wired Magazine Group, Inc., pp. 138-148.

"How Hydrogen Power Can Change the World," The Economist, October 25-31, 1997.

Ballard Power Systems, Inc., 1997 Annual Report.

APPENDIX D

The Center for Fuel Cell Research and Applications

A Shared Research Laboratory Program

of the

Houston Advanced Research Center

HARC

- 501 (C) (3) private, nonprofit research and technology organization.
- Technology demonstration and transfer.
- 15 years experience with managing collaborative research program
  - synergy, IP management, shared costs
- Neutral, non-competitive third party
- Linked to 10 collaborative universities

HARC

The 'Industry Consortia' Concept

- Core program
  - 6 Industries form core group
  - 3 year commitment to provide latest fuel cells and infrastructure.
  - Advisory board drives the research
  - Support staff provides technical follow through
- Ancillary Projects: focused projects outside the core program.

Key Objectives

- Analyze PEM and other fuel cell technologies.
- Evaluate fuel cell system's emissions.
- Evaluate operations with differing fuels.
- Research environmental and safety aspects.
- Establish reliability and operational characteristics.
- Establish a university linked fellowship program

HARC

Fuel Cell Background

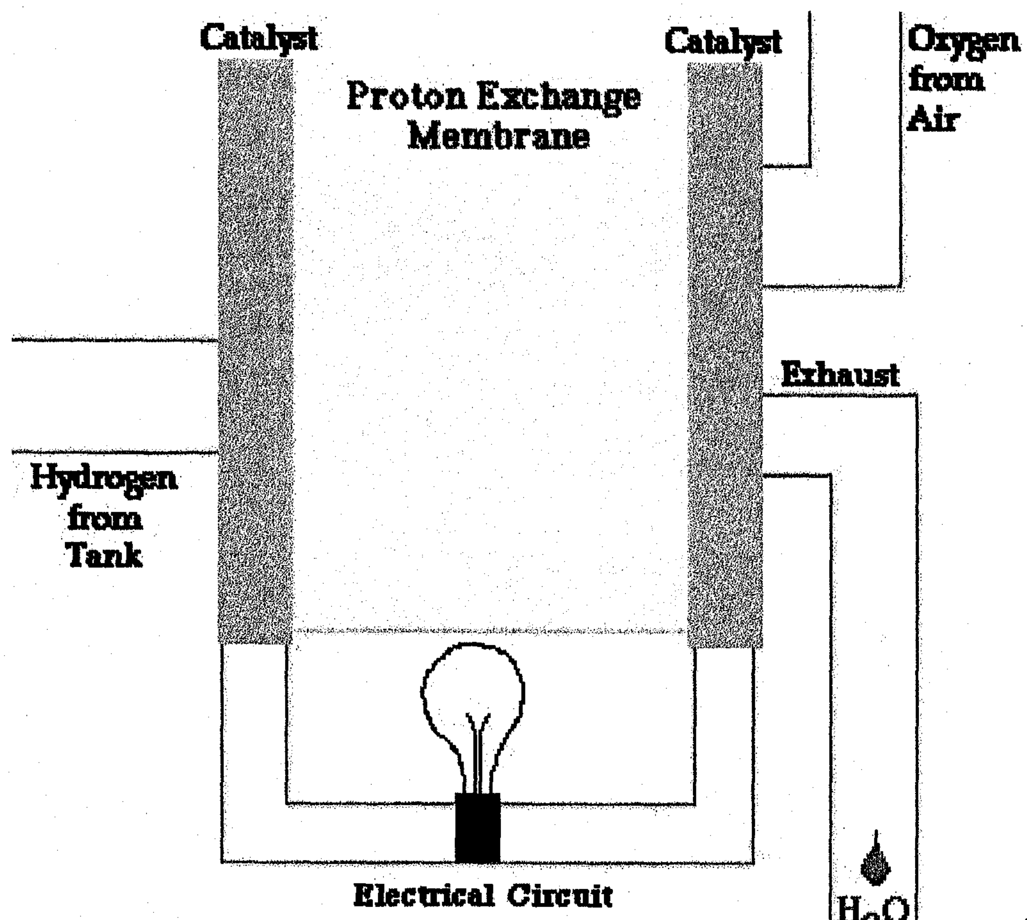
- Invented in 1839
- Used in spacer program since 1960's
- Currently five types of fuel cells
- All use catalysts to drive the reactions
- Phosphoric acid and Proton Exchange Membrane cells best commercial technologies.

Fuel Cell Characteristics

- A chemical reaction creates free electrons.
- No combustion required.
- Using a fuel (reactant) and catalyst they produce continuous clean quite power.
- By products are electricity and heated H_2O
- Can use a number of fuels that contain H_2
  - H_2, methane, methanol, butane, propane,etc.

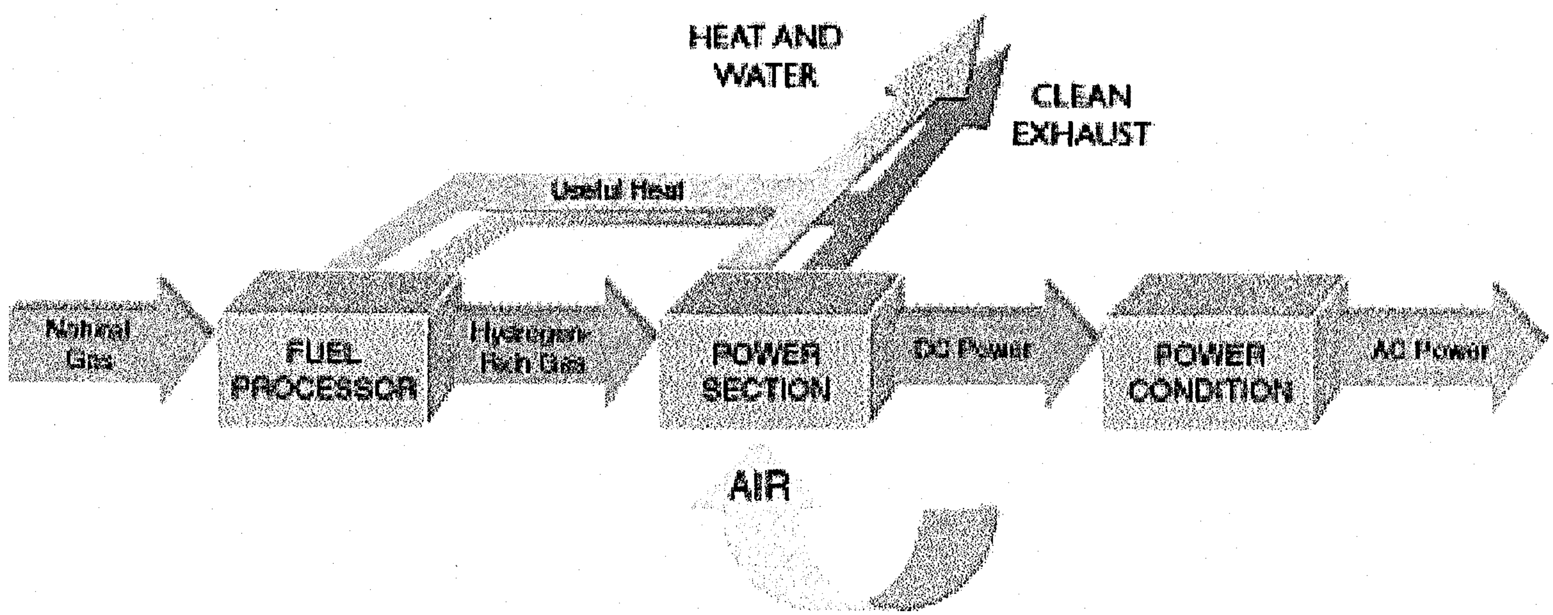
HARC

Operation of PEM Fuel Cell



HARC

Fuel Cell System



HARC

Key Benefits of Participation

- Access to critical evaluation of commercial and pre-commercial fuel cell technology.
- Shared costs and risks.
- Consortia synergism.
- Applications Focus.
- Experienced research management.
- Access to trained staff and students.

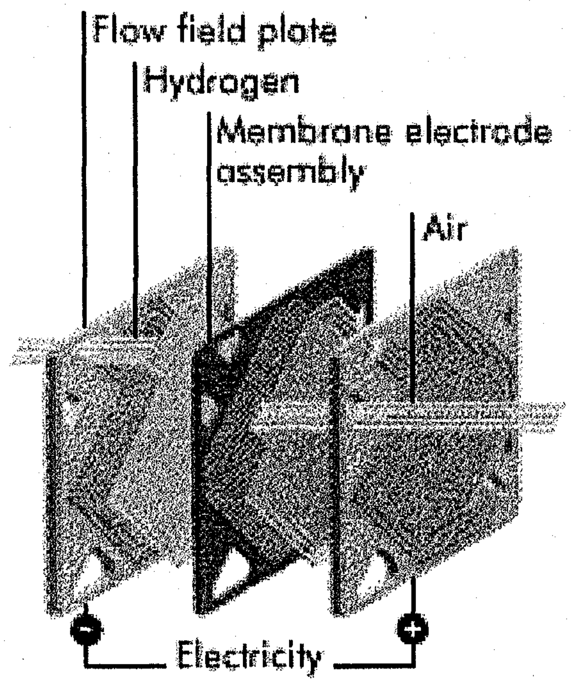
HARC

Initial Projects

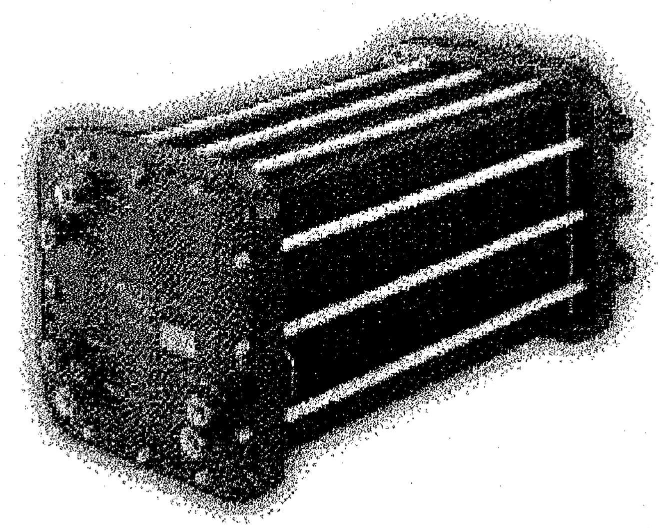
- 1-10KW Fuel Cells
  - Analyze full cycle emissions data
  - Integrated fuel cell systems for homes
  - Operations with various fuels
  - Demonstrate power quality and reliability
  - Develop strategies for peak and dynamic loads
  - Analyze issues: siting, installation, monitoring and maintenance

HARC

PEM Fuel Cell Details



Single Cell layout



Cell Stack

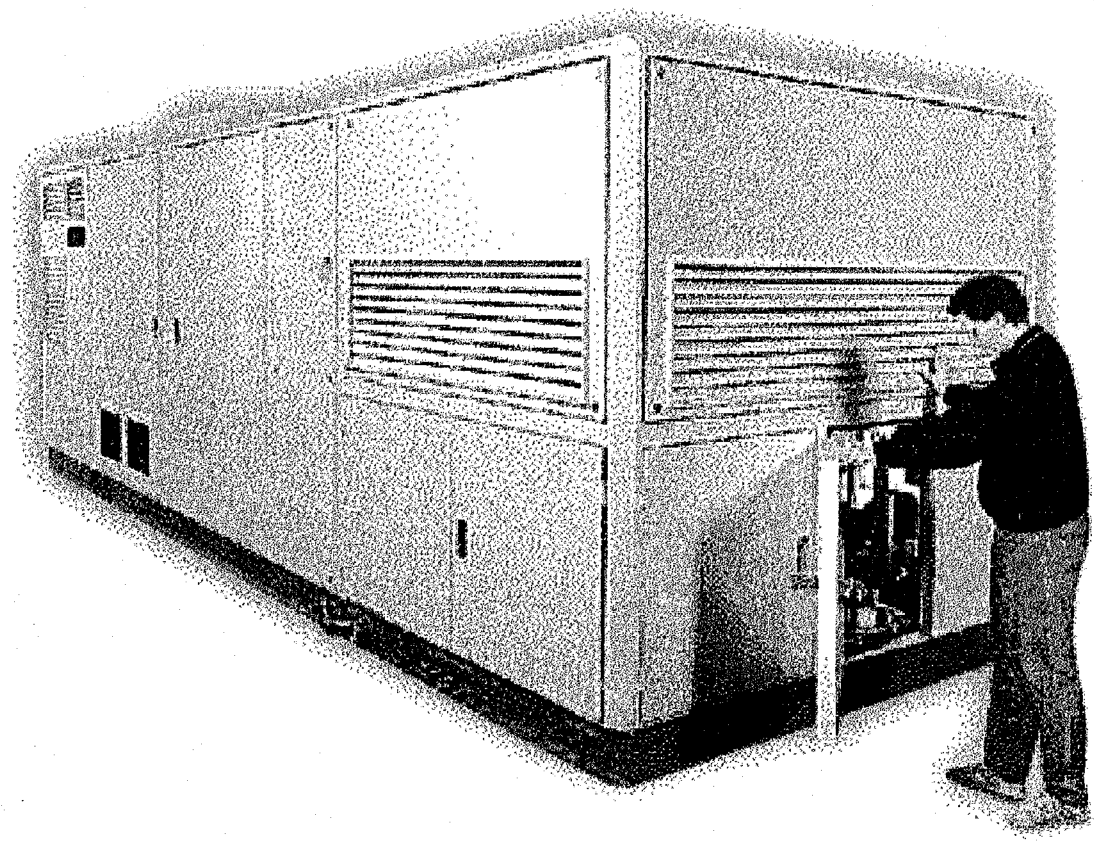
HARC

Initial Projects

- 250 KW Fuel Cells
  - Explore issues of integration with the grid
  - Analyze air quality emissions
  - demonstrate feasibility of Emission Reduction Credits.
  - Monitor operations, efficiency and ongoing maintenance.
  - Research benefits of integrated heat recovery.

HARC

Ballard 250 KW Fuel Cell Unit



HARC

Deliverables

- Quarterly Management Report
- Experimental Results 'Data Base'
- Experiment tracking and reporting
- Semi annual Review Meeting
- Annual Financial Report and Audit
- 'Hi-Lite' Flash Reports

HARC

Appendix E
Fuel Cell Educational Paper

Fuel Cells and Distributed Energy

David J. Norton, Ph.D.
Houston Advanced Research Center

Introduction

The three important trends are driving changes in the way electrical energy is produced and delivered.

- Deregulation of traditional utilities: Separation of generation and transmission, power wheeling, power marketing, ...
- Increased global concern about long term effects of pollution: Global warming, the ozone hole, regional smog and haze, burning of forests, California rules ...
- Development of technologies which enable distributed energy generation: Reformers, Fuel cells, fly wheels, ultra-capacitors, micro-turbines, ...

The current glut of fossil fuels in the marketplace is erasing any energy conservation gains made after the energy shortages of the 70's and 80's. Further, as the US becomes more affluent, we are heating larger homes with fewer occupants and driving more miles in larger vehicles. The use of fossil fuels in this country is also growing due to a gradual reduction in nuclear power that further compounds the problem. Our added energy consumption combined with the increasing demand of the second and third world countries is leading to environmental crisis and a growing dependence on foreign energy sources[1].

Fuel Cell Technology.

Fuel Cell Basics

Fuel cells were discovered in 1839. Perhaps the most well known application has been the alkaline fuel cell that provides power on the space shuttle. Only in the last decade have fuel cells been considered as a potential commercial source of energy for transportation and stationary applications. Fuel cells generate electricity with no moving parts by taking advantage of certain

[1] The New York Times, U.S. Splurging on Energy After Falling Off Its Diet, Thursday October 22, 1998

electrochemical reactions that release electrons. Fuel cells can be very efficient in the use of fuels and produce much less environmental load than due combustion devices.

There are many electrochemical reactions that can be utilized to create electricity from the reaction of a fuel. Each requires different materials and technologies to make them work. Several systems have been demonstrated and some have been sold commercially. In the order of nominal operating temperature, they include:

- Solid Oxide (1830 ^{O}F)
- Molten Carbonate (1100 ^{O}F)
- Phosphoric Acid (400 ^{O}F)
- Alkaline (320 ^{O}F)
- Proton Exchange Membrane (180 ^{O}F)

The most simple and flexible of these is the proton exchange membrane (PEM) system. Using this technology, hydrogen is used as a fuel to react with oxygen to release 2 electrons for every molecule of water produced.

In its purest form, PEM Fuel cells use pure hydrogen and oxygen to create electricity, heat and water. There are virtually no other effluents. The efficiency in terms of the production is higher than any other means of conversion. In addition, since there is no combustion, there is no NO_2 or NO produced or, for that matter, any other pollutants. The basic components of a PEM fuel cell are shown in Figure 1.

As a practical matter, there are two issues that the use of hydrogen introduces.

- <u>Hydrogen is not widely available.</u> Since it is not nationally distributed it is difficult to plan commercial projects using hydrogen. It can be made using the output of solar cells to split water into hydrogen and oxygen. It can also be made by "reforming" a fossil fuel rich in hydrogen. However, both of these processes require additional energy.
- <u>Hydrogen is the lightest gas</u>. Therefore, it occupies a large volume. This represents a problem for mobile systems and is problematic for stationary systems. Compressed gas or cryogenic liquid hydrogen represent alternative ways to store hydrogen.

Likewise pure oxygen, O_2 is not readily available, however, it can easily be obtained from the air. It can be stored as either a compressed gas or as cryogenic liquid.

Components of a Practical Fuel Cell System

There are at least three basic components in a fuel cell system. 1) The reformer which converts the fuel of choice into hydrogen, 2) the fuel cell which reacts the hydrogen to oxygen to produce the electricity and, 3) the load adapter that matches the DC output of the fuel cell with a dynamic load. Fuel cells typically produce low voltage and high amperage power that must be adapted to fit the load. The load may be AC as it would be for most buildings and homes. Or, it may be DC for driving electric motors in automobiles. As schematic of a typical fuel cell system is presented in Figure 2.

In most cases the load will have a dynamic character. The dynamic part of the load results from acceleration of a automobile or the need to supply extra current when a large appliance turned on. Therefore, one of the characteristics that are important in evaluating fuel cell systems is how they perform in Load Following applications. Close load following is in some cases desirable, however, it tends to be contrary to high efficiency and low costs. Load following has implications for the Reformer as well as the fuel cell and load adapter.

Commercial Applications

Fuels for Fuel Cells

Because of the volume and availability issues associated with hydrogen, for serious commercial applications alternative fuel are desirable. Therefore, a fuel such as, natural gas (primarily methane, CH_4) or, methanol is often considered. Because of its broad use at home and in industry, natural gas is a strong candidate for stationary applications. Further, methane has the highest hydrogen to carbon ratio of any fossil fuel which means it provides the most energy per unit of weight and the least amount of CO_2.

For transportation systems, there is still a storage problem that requires gases to undergo either high levels of compression or liquifaction. Alternatively, moving to butane or propane makes it possible to store the gas as a liquid at fairly low levels of pressure. Because methanol exists as a liquid at standard temperature and pressure, it is considered a strong possibility for transportation applications. This eases the handling and safety problems and is reminiscent of current gasoline technology.

The Reformer

Using any fossil fuel introduces some complexity to the operation of a fuel cell. A reformer is needed to produce hydrogen and to strip away any unwanted pollutants or catalyst contaminants. The actual process of making hydrogen from methane is not too complex and can actually use some of the waste heat created by the fuel cell. All that is needed is sufficient heat to break the molecular bonds between the carbon atom and the hydrogen atoms. The heat is used to create steam that is used in the reforming process.

The oxygen required by the fuel cell is taken from the air and matched up with the liberated hydrogen. All of this adds some complexity and requires a small fraction of the energy available to reform the fuel into hydrogen. Reformers require an interval time before they are ready to produce hydrogen from the fuel. Obviously, if they use heat from the fuel cell there would be a delay. Another approach is to burn a small portion of the fuel to create the necessary steam. But in any case there would be a small time delay before the fuel cell reaches full operational levels and some of the energy otherwise available for electric power is diverted away to the reformer function.

Automotive Fuel Cell

In California, the call for 10% Zero Emission vehicles (ZEV) by the year 2004 has started a chain reaction. It has prompted well over ½ billion dollar of investment by the auto and fuel companies to perfect the fuel cell for automotive use. Companies like Ballard of Canada and others in the US are recipients of these investments. Big companies like Daimler Benz, Ford and Toyota are leading the way. The result is as steady decline in cost and improvement in performance and robustness. Fuel companies like Shell and Texaco are vying to become energy companies and want to be sure they are producing the fuel of choice for fuel cells be it hydrogen, pure methane or, methanol.

Stationary Fuel Cell Systems

The need for an automotive fuel cell is fairly well defined. The increase in efficiency and the reduction of dangerous pollutants that fuel cells provide make a clear case over the internal combustion engine. The stationary market is still driven by the need to compete against grid power. There are already commercial stationary fuel cells on the market. Most notable among them is the ONSI Phosphoric acid 200KW unit which has been sited in over 25 locations around the world. Typical applications are for supplemental power for buildings in environmentally sensitive situations.

The tremendous investment in fuel cell R&D for automobile units is leading to improvements in cost and performance of stationary fuel cells. Potential markets for stationary units include:

- Power generation for the home,
- Power for buildings,
- Power generation at the well head or along pipelines using natural gas,
- Portable power systems,
- Premium power systems, or un-interruptible power systems (UPS)

We are now seeing companies like Detroit Edison and GE entering the fray by buying into smaller fuel cell companies to gain access to their technology. Partnerships and joint ventures are being developed all around the world looking for ways to leverage fuel cell technology into products and services for tomorrow.

It is entirely possible that deregulation will lead to the increase in electrical costs for individual homes and small businesses. This may make distributed generation economically viable at the home. There is already a potential market for fuel cells in communities where the electricity costs are high but natural gas is plentiful. The price per unit will need to be in the $3,000 to $4,000 range. When the full benefits of the automobile R&D are translated to stationary systems this should not be a barrier. Many utilities are trying to decide how they want to position themselves relative to these developments. Should they offer fuel cells to their customers? Should they create a favorable relationship with current or potential manufacturers?

Connecting to the Load

In reality it is the load that drives the fuel cell. The load is usually a dynamic function that represents the power needs of a house, a building or an automobile. While fuel cells have a capacity for load following, the times required for the system to respond is measured in seconds. On the other hand the electrical loads associated with starting motors and heaters may be require response in fractions of seconds. Similarly, automobile applications may need rapid acceleration. In these cases, it is desirable to have energy caches in the form of energy storage devices. A few possible devices to produce short term peak power are listed below:

- Batteries
- Flywheels
- Ultra-capacitors
- Other energy storage devices

These devices work in concert with the fuel through the load adapter. The load adapter manages the energy resources for optimum performance and potentially recaptures kinetic energy in transportation systems. The relationship between the various components is shown in Figure 2.

Increasing the Energy Density.

In some circumstances, it is desirable to increase the amount of energy that can be produced in a given volume of space. Obviously, this is the case for transportation applications, but it is largely true for large stationary units as well. By increasing the operating pressure from 1 atmosphere to 3 - 5 atmospheres, the amount of hydrogen processed increases in almost direct proportion to the pressure. Pressurization, however, is an energy cost which must come out of the fuel cell hence there is reduction in efficiency. Some of the energy produced by the fuel cell is lost to run the compressor. If a turbine and perhaps a heat exchanger is added some of the compression losses can be regained. Increasing the pressure can also allow the fuel cell to follow dynamic loads more effectively. These extra components are typically only justified when creating large stationary units.

Conclusion

Fuel cells fill a need to provide highly efficient and low pollution power in number of applications. Currently, fuel cells technology is being funded heavily by the automotive industry and, although less, the electric power industry. The U.S. DOE and DOD also have interest in fuel cells and support several demonstration projects. Picking winners among the various competing technologies by the government has proven difficult. Fuel cells will be an international technology driven by industry.

Teams comprised of companies with specific expertise or market share are now forming on a worldwide basis. Fuel providers are scrabbling to anticipate the fuels needed, and they are working with the companies that understand the reformer technology. Whole new ideas for drive trains and traction are under development.

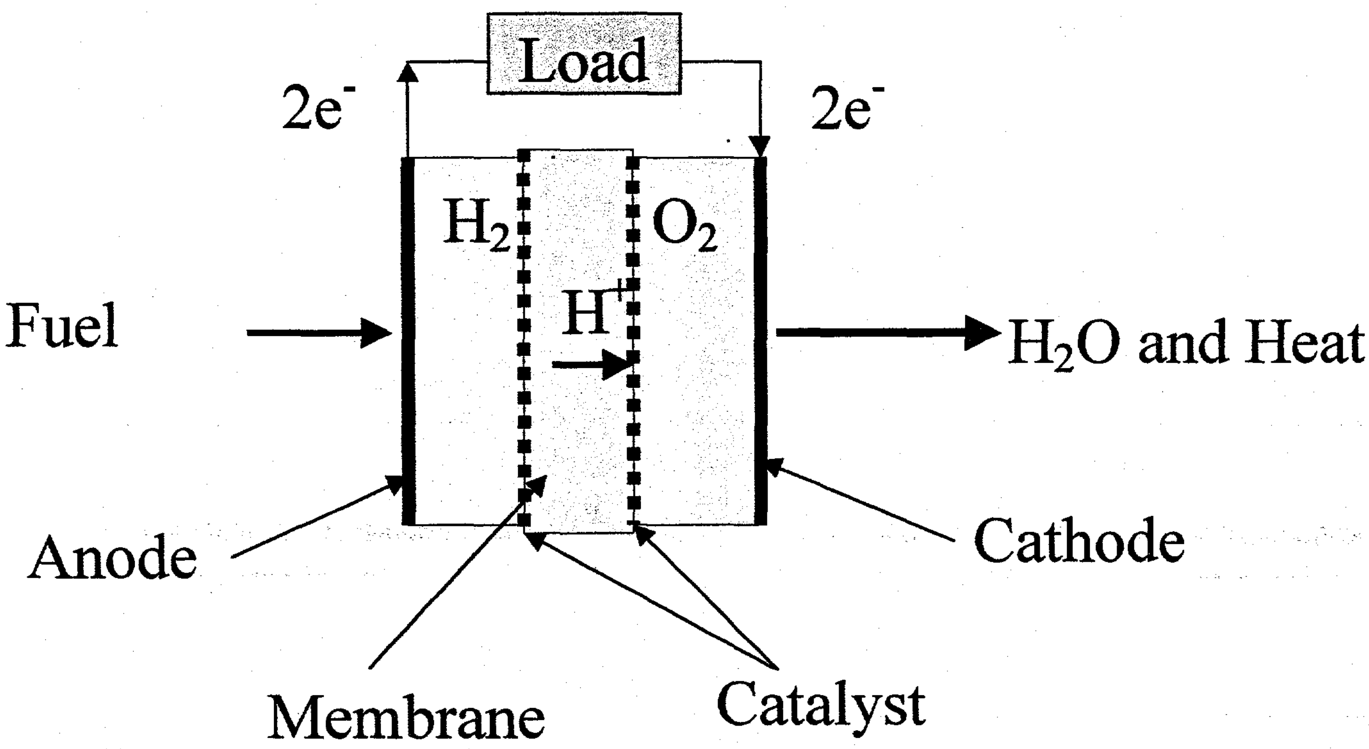


Figure 1. A schematic of the components of a simple H_2/O_2 PEM fuel cell.

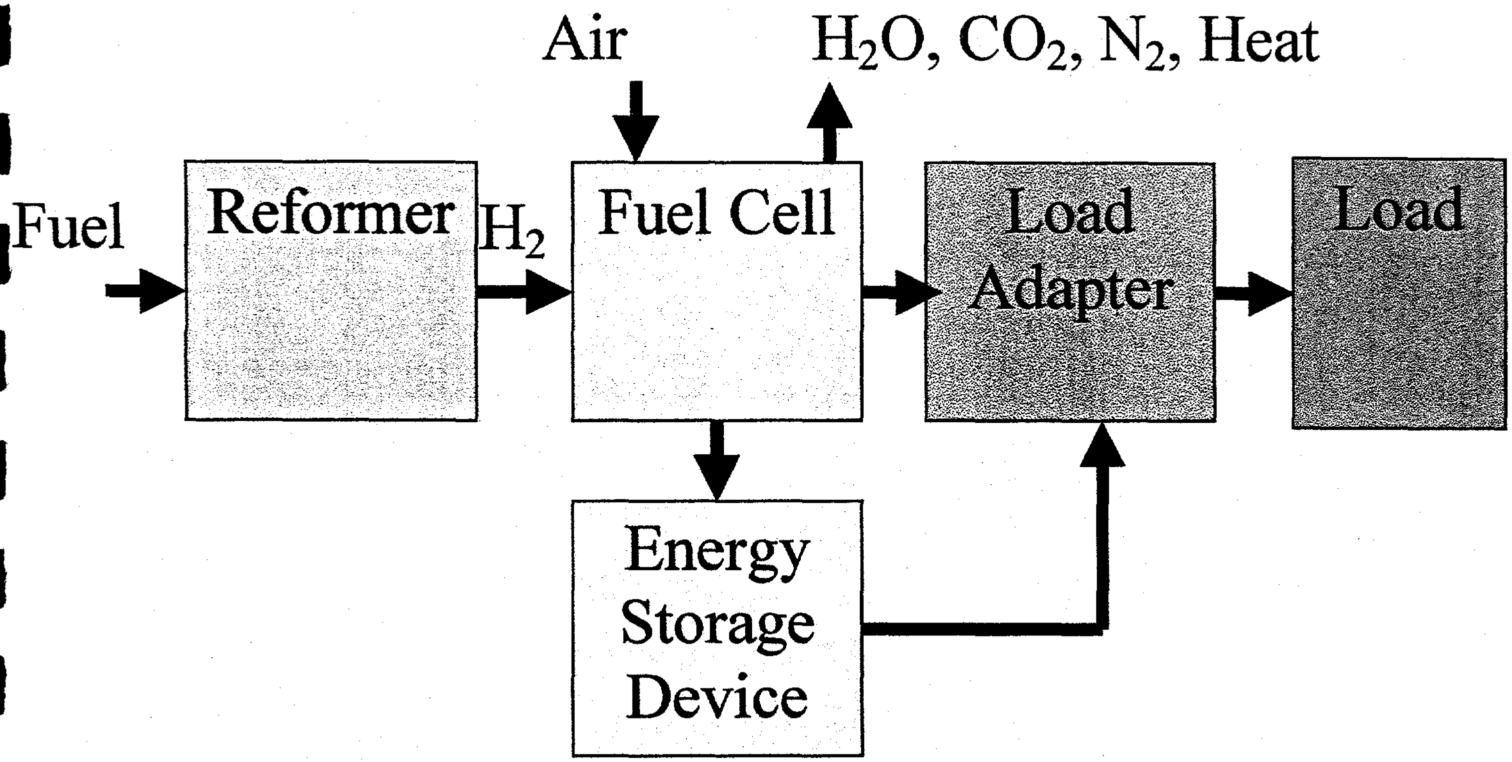


Figure 2. A fuel cell system with a load adapter and an energy storage device.

Appendix F

Draft agreement with NASA JSC

AGREEMENT BETWEEN

NASA LYNDON B. JOHNSON SPACE CENTER
AND
HOUSTON ADVANCED RESEARCH CENTER

The LYNDON B. JOHNSON SPACE CENTER of the NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (hereinafter referred to as "JSC"), and HOUSTON ADVANCED RESEARCH CENTER (hereinafter referred to as "HARC"), desire to enter into this Agreement.

The Agreement is favorable for NASA because HARC's objective to perform proton exchange membrane (PEM) fuel cell applied research to establish economic impacts of operation, effectiveness of fuel cells integrated into a power grid, reactant processing alternatives, system reliability, maintenance requirements, and emissions data are supportive in many areas with NASA PEM fuel cell development goals. Operation of PEM fuel cells by HARC in its newly created Center for Fuel Cell Research and Applications (CFCRA) will generate data substantiating strengths and weaknesses of fuel cell configurations along with reactant supply alternatives, an area of interest to Human Exploration and Development of Space initiatives which may use fuel cells as power sources. The CFCRA will provide basic and applied research opportunities associated with the PEM fuel cell with the goal of solving technical and financial barriers to widespread terrestrial use. Those research areas will offer opportunities for improvement in PEM fuel cell performance and economics that may benefit NASA's future missions.

The Agreement offers benefits to HARC by allowing access to NASA's non-proprietary technical expertise in fuel cell test stand design, facility requirements specification, testing, operations, and system development. NASA's engineering experience with fuel cells includes both PEM and alkaline configurations with tests currently on-going for PEM fuel cells. NASA's experienced personnel and its unique test facilities provide the CFCRA a valuable resource that can be utilized in formulating, implementing, and solving fuel cell applications issues that will arise during the fuel cell research initiative.

The parties mutually agree to the following:

ARTICLE I -- GENERAL PROVISIONS

A. JSC and HARC designate the following individuals as points of contact for coordinating, administering, managing, and monitoring the activities of their respective parties under this Agreement:

National Aeronautics and Space Administration
Lyndon B. Johnson Space Center
2101 NASA Road 1
Houston, TX 77058
Attn: William Hoffman, Mail Code: EP5

and

Houston Advanced Research Center
Center for Fuel Cell Research and Applications
ATTN: ~~David Norton~~Dan G. Davis
4800 Research Forest Drive
The Woodlands, Texas 77381

B. Both parties agree that all news releases, press statements, advertisements or publicity arising out of activities related to this Agreement, shall be subject to prior written approval of the both parties. This provision shall survive the termination or expiration of this Agreement.

C. HARC agrees that, for the duration of this Agreement, and while on JSC premises, its employees, agents, contractors, subcontractors, and principal investigators shall comply with all laws and applicable regulations, instructions, and directives, including, but not limited to, those pertaining to safety and security.

D. It is understood that any commitment by either party of facilities, equipment, supplies, and/or services, in furtherance of the objectives of this Agreement, shall be on a no-cost, mission non-interference basis, subject to availability and approval. Furthermore, while both parties agrees to apply its best efforts to assure that said facilities, equipment, supplies, and/or services, will function reliably for their intended use or purpose, nothing in this Agreement shall be construed to imply that either party warrants or makes any representations as to the quality of their performance or operation.

E. Both parties agree to put forth their best efforts and cooperate in good faith to achieve the objectives of this Agreement. It is mutually agreed, however, that the services contemplated by this Agreement shall not be given priority over any other JSC agreement or program nor be performed in any manner which interferes with JSC's overall mission.

F. HARC agrees that nothing in this Agreement shall be construed to imply that NASA endorses or sponsors any product or service resulting from activities conducted under this Agreement, regardless of the fact that such product or service may employ NASA developed technology. With the limited exception of factually accurate statements of use by, development by or for, or in connection with NASA, HARC agrees to refrain from the written use of the words "National Aeronautics and Space Administration" or the letters "NASA", or a combination, variation, or colorable imitation thereof (including the logo), either alone or in combination with other words or letters, in connection with any product or service being offered or made available to the public in a manner reasonably calculated to convey the impression that such product or service has the endorsement or sponsorship of NASA.

ARTICLE II -- RESPONSIBILITIES OF HARC

A. HARC agrees to work with JSC to explore innovative uses for PEM fuel cell technologies and systems engineering methods developed within the Center for Fuel Cell Research and Applications, a research branch of HARC.

B. HARC will provide access to technical staff and management for performance and nonproprietary operational data developed by the CFCRA on mutually supported and/or nonproprietary tasks for the duration of this Agreement.

C. HARC will consider providing access to equipment and personnel on a non-interference basis to perform evaluation, testing, and analysis in support of fuel cell system and component studydesign.

ARTICLE III -- RESPONSIBILITIES OF JSC

A. A. JSC will provide access to engineers and technologists experienced with PEM and alkaline fuel cell testing, fuel cell test facility requirements, design, and failure modes on a non-interference basis.-

B. JSC will also provide access to PEM test stands on a non-interference basis for evaluation of technologies and configurations of mutual interest.

B. C. JSC will work with HARC to investigate technologies and methods which offer promise in reducing the costs and operational risks of PEM fuel cells intended for both terrestrial and space applications.

C. JSC will provide temporary space for displays, conferences, and other activities requested by HARC on a non-interference and space available basis.

D. JSC will provide current non-proprietary information on PEM fuel cell conceptual designs, operational constraints, integration issues, performance requirements, and test information.

E. JSC agrees to consider the loaning of equipment and personnel as required to perform evaluation, testing, and analysis in support of fuel cell systems and component study.

D. JSC will provide current, non-proprietary information regarding PEM fuel cell conceptual designs, operational constraints, integration issues, performance requirements, and test information missions being studied, including mission models, design references, and information releasable to the general public.

ARTICLE IV -- FUNDING

A. Nothing in this Agreement shall be construed to imply any commitment of JSC's or HARC's funds or appropriations to each other. In addition, JSC's resource commitments to the Agreement are subject to availability of appropriated funds, and nothing herein may be construed as implying that the United States Congress will appropriate funds at a later date to discharge JSC's obligations hereunder.

ARTICLE V -- LIABILITY OF THE PARTIES

A. The parties agree to a no-fault, no-subrogation interparty waiver of liability under which each party agrees to be responsible for any damage it sustains under this Agreement, which damage is caused by JSC or HARC during the Agreement, whether such damage arises through negligence or otherwise.

B. As to third party claims, HARC agrees to indemnify and hold the U.S. Government and its contractors and subcontractors harmless from any claim, judgment, or cost arising from the injury to or death of any person, or for damage to or loss of any property attributable to HARC through its employees, agents, contractors, subcontractors, or principal investigators arising as a result of activities expressly or implicitly covered under this Agreement, whether such injury, death, damage, or loss, is caused by negligence or otherwise.

ARTICLE VI -- PATENT AND INVENTION RIGHTS

A. The term "Participant," as used herein means any non-U.S. government entity that is a signatory to this Agreement. The patent and inventions rights set forth herein are applicable to any employees, contractors or subcontractors, or other entities having a fiduciary or contractual relationship with Participant that are assigned, tasked, or contracted with to perform specified Participant activities under this Agreement.

B. General: Title to inventions made (conceived or first actually reduced to practice) as a consequence of, or in direct relation to, the performance of activities under this Agreement will remain with the respective inventing parties (HARC or NASA), and no patent or invention rights are exchanged between or granted by such parties under this Agreement except as provided herein.

C. NASA Inventions: NASA will use reasonable efforts to report inventions made by NASA employees as a consequence of or which bear direct relation to, the performance of specified NASA activities under this Agreement. NASA will use reasonable efforts to grant HARC, in accordance with 37 CFR 404, an exclusive or partially exclusive, revocable, royalty-bearing license, on terms to be subsequently negotiated to any NASA invention which may be made under the Agreement. This license will be subject to the rights reserved in paragraph F(1), below.

D. NASA Contractor Inventions: In the event NASA contractors are tasked to perform work in support of specified NASA activities under this Agreement and inventions are made by contractor employees or jointly between NASA employees and contractor employees, and NASA has the right to acquire or has acquired title to such inventions, NASA will use reasonable efforts to report such inventions. NASA will use reasonable efforts to grant HARC, in accordance with 37 CFR 404, an exclusive or partially exclusive, revocable, royalty-bearing license, on terms to be subsequently negotiated, to any NASA invention which was made under the Agreement. This license will be subject to the rights reserved in paragraph F (2), below.

~~D.~~ B. Joint Inventions With HARC: NASA and HARC agree to use reasonable efforts to identify and report to each other any inventions made jointly between NASA employees (or employees of NASA contractors) and employees of HARC, and upon timely request NASA may agree to refrain from exercising its undivided interest in a manner inconsistent with HARC's commercial interests and to cooperate with HARC in obtaining patent protection on its undivided interest, subject to the applicable rights reserved in paragraph G, below.

F. HARC Inventions: Inventions and proprietary data conceived or developed solely by HARC and arising directly out of the course of this Agreement shall remain the property of HARC. No patent or invention rights are granted by HARC under this Agreement.

F. Reservations in HARC's License: Any license granted to HARC pursuant to paragraphs C, D or E above will be subject to the following rights:

(1) as to inventions made solely by, or jointly with NASA employees, the irrevocable, royalty-free right of the government of the United States to practice and have practiced the invention by or on behalf of the United States and on behalf of any foreign government or international organization pursuant to any existing or future treaty or agreement with the United States; and

(2) as to inventions made solely by, or jointly with, employees of NASA contractors, the rights in the government of the United States as set forth in (l) above, as well as the revocable, nonexclusive, royalty-free license in the contractor as set forth in 14 CFR 1245.108.

G. Protection of Reported Inventions: When inventions are reported and disclosed between the parties in accordance with the provisions of this clause, the receiving party agrees to withhold such reports or disclosures from public access for a reasonable time (presumed to be one year unless otherwise mutually agreed) in order to facilitate the allocation and establishment of the invention and patent rights under these provisions.

H. Patent Filing Responsibilities and Costs: The invention and patent rights set forth herein shall apply to any patent applications filed and patents obtained in any country, and each party is responsible for its own costs of preparing, prosecuting, issuing, and maintaining patents covering sole inventions in any country; except that NASA and HARC may, upon the reporting of any invention (sole or joint) or in any license option granted, mutually agree otherwise for any country as to patent application preparation, filing and prosecution responsibilities and costs, and maintenance responsibilities and costs. As to any invention made jointly between NASA employees (or employees of a NASA contractor) and employees of HARC and for which HARC files a patent application, HARC agrees to include the following statement therein:

The invention described herein may be manufactured and used by or for the United States government for United States government purposes without the payment of royalties thereon or therefor.

ARTICLE VII -- RIGHTS IN DATA

A. The term "Participant," as used herein means any non-U.S. government entity that is a signatory to this Agreement. The rights in data set forth herein are applicable to any employees, contractors or subcontractors, or other entities having a fiduciary or contractual relationship with Participant that are assigned, tasked, or contracted with to perform specified Participant activities under this Agreement.

The term "data," as used herein, means recorded information, regardless of form, the media on which it may be recorded, or the method of recording. The term includes, but is not limited to, data of a scientific or technical nature, computer software and documentation thereof, and data comprising commercial and financial information.

B. General: Data exchanged between NASA and Participant under this Agreement will be exchanged without restriction as to its disclosure, use, or duplication except as otherwise provided below in this article.

C. Background Data: In the event it is necessary for Participant to furnish NASA with data which existed prior to, or was produced outside of this Agreement, and such data embodies trade secrets or comprises commercial or financial information which is privileged or confidential, and such data is so identified with a suitable notice or legend, the data will be maintained in confidence and disclosed and used by NASA and its contractors (under suitable protective conditions) only for the purpose of carrying out NASA's responsibilities under this Agreement. Upon completion of activities under this Agreement, such data will be disposed of as requested by Participant.

D. Data Produced by Participant under this Agreement: In the event data first produced by Participant in carrying out Participant's responsibilities under this agreement is furnished to

NASA, and Participant considers such data to embody trade secrets or to comprise commercial or financial information which is privileged or confidential, and such data is so identified with a suitable notice or legend, the data will be maintained in confidence and disclosed and used by the government and its contractors (under suitable protective conditions) only for the subject research and development by or on behalf of the government. In the event that data is produced by the Participant using JSC facilities and not involving NASA personnel or NASA Contractors but which embodies trade secrets or would comprise commercial information will not be disclosed to NASA and may be used by the Participant for any purpose whatsoever without restriction on disclosure and use.

E. Data Produced by NASA: As to data first produced by NASA in carrying out NASA's responsibilities under this agreement and which data would embody trade secrets or would comprise commercial or financial information that is privileged or confidential if it had been obtained from Participant, such data will, to the extent permitted by law, be appropriately marked with a notice or legend and maintained in confidence for a period of 5 years after development of the information, with the express understanding that during the aforesaid period such data may be disclosed and used (under suitable protective conditions) by or on behalf of the government for government purposes only, and thereafter for any purpose whatsoever without restriction on disclosure and use. Participant agrees not to disclose such data to any third party without NASA's written approval until the aforementioned restricted period expires.

F. Data disclosing an invention: In the event data exchanged between NASA and Participant discloses an invention for which patent protection is being considered, the disclosure and use of such data is not otherwise limited or restricted herein, and the furnishing party specifically identifies such data, the receiving party agrees to withhold such data from public disclosure for a reasonable time (presumed to be one year unless mutually agreed otherwise) in order for patent protection to be obtained.

G. Copyright: In the event data is exchanged with a notice indicating that the data is protected under copyright as a published, copyrighted work, the following paid-up licenses shall apply:

- If the data existed prior to, or was produced outside of this agreement, the receiving party and others acting on its behalf, may reproduce, distribute, and prepare derivative works for the purpose of carrying out the receiving party's responsibilities under this agreement; and

- If the data does not contain a copyright notice, it will be assumed that the data was first produced under this Agreement, and the receiving party and others acting on its behalf, may reproduce, distribute, and prepare derivative works for any of its own purposes.

H. Oral and visual information: If information which Participant considers to embody trade secrets or to comprise commercial or financial information which is privileged or confidential is orally or visually disclosed to NASA, such information must be reduced to a tangible, recorded form (*i.e.*, converted into data as defined herein), identified and marked with a suitable notice or legend as required by paragraphs C and D, above, and furnished to NASA within 10 days after such oral or visual disclosure, or NASA shall have no duty to limit or restrict, and shall not incur any liability for, any disclosure and use of such information.

I. Disclaimer of Liability: Notwithstanding the above, NASA shall not be restricted in, nor incur any liability for, the disclosure and use of :

(1) data not identified with a suitable notice or legend as set in paragraphs C and D of this Article; nor

(2) information contained in any data for which disclosure and use is restricted under paragraphs C, D and F, above, if such information is or becomes generally known without breach of the above, is known to or is generated by NASA independently of carrying out responsibilities under this Agreement, is rightfully received from a third party without restriction, or, is included in data which Participant has, or is required to, furnish to the U.S. government without restriction on disclosure and use.

ARTICLE VIII -- CONSENT FOR ASSIGNMENT

Neither this Agreement nor any interest arising under it shall be assigned by either party without the written consent of the other party.

ARTICLE iX -- EFFECTIVE DATE, DURATION, AND TERMINATION

This Agreement shall become effective upon the date of the last signature hereto, and will remain in effect for 2 years. This Agreement may be unilaterally terminated by either party upon 30 days written notice and may be terminated at any time upon mutual written agreement of both parties.

ARTICLE X -- AUTHORITY

This Agreement is entered into by the Director of Engineering, LYNDON B. JOHNSON SPACE CENTER, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION, in accordance with authority set forth in Sections 203(c)(5) and 203(c)(6) of the National Aeronautics and Space Act of 1958, as amended, and NMI 1050.9A and redelegation of authority letter, dated October 25, 1991.

[Signature Page Follows]

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

By: ______________________________
Leonard S. Nicholson
Director of Engineering
Lyndon B. Johnson Space Center

____
Date

HOUSTON ADVANCED RESEARCH CENTER

By: ______________________________
Dan G. Davis
Chief Operating Officer

____
Date