Fuel Cell Technology

Southwest Research Institute®
San Antonio, Texas

About the Cover: *SwRI engineers use small-scale fuel cells to screen new materials and to evaluate fuel-cell operating conditions.*

Fuel cells are becoming an important part of the world's energy mix. Southwest Research Institute® (SwRI®) is highly qualified to support the fuel cell community in developing and improving these important energy conversion devices.

The Institute's wide range of expertise enables conception and development of new fuel cell chemistries and architectures, enhancement of chemical conversions and manufacturing processes, and integration of fuel cells with the devices they power. SwRI promotes innovative approaches to fueling infrastructure, fuel cell construction, waste heat utilization, and power control and storage.

To complete the fuel cell systems, engineers develop ancillary processes such as fuel processors, fuel storage, delivery, and cleanup systems, and formulate and develop custom catalysts for fuel reforming and emissions reduction. In addition, SwRI engineers have extensive experience in addressing safety issues and providing failure mode analysis.

Institute divisions working in fuel cell development and testing have achieved certification to ISO 9001 and 9002 standards, ensuring compliance with stringent quality control procedures in design, development, research, and testing. All programs remain confidential and any intellectual property rights resulting from contract research are assigned to the client.

SwRI has extensive expertise in a wide range of fuel cell-related technologies, including:

- Material sciences
- Fuel processor testing and development
- Modeling and optimization
- Systems development and integration
- Test, measurement, and characterization
- Manufacturing systems technology

Material Sciences

For fuel cell technologies to become commercially accepted, new high-performance, low-cost materials must be developed. SwRI is playing a major role in developing novel materials and processes in areas such as:

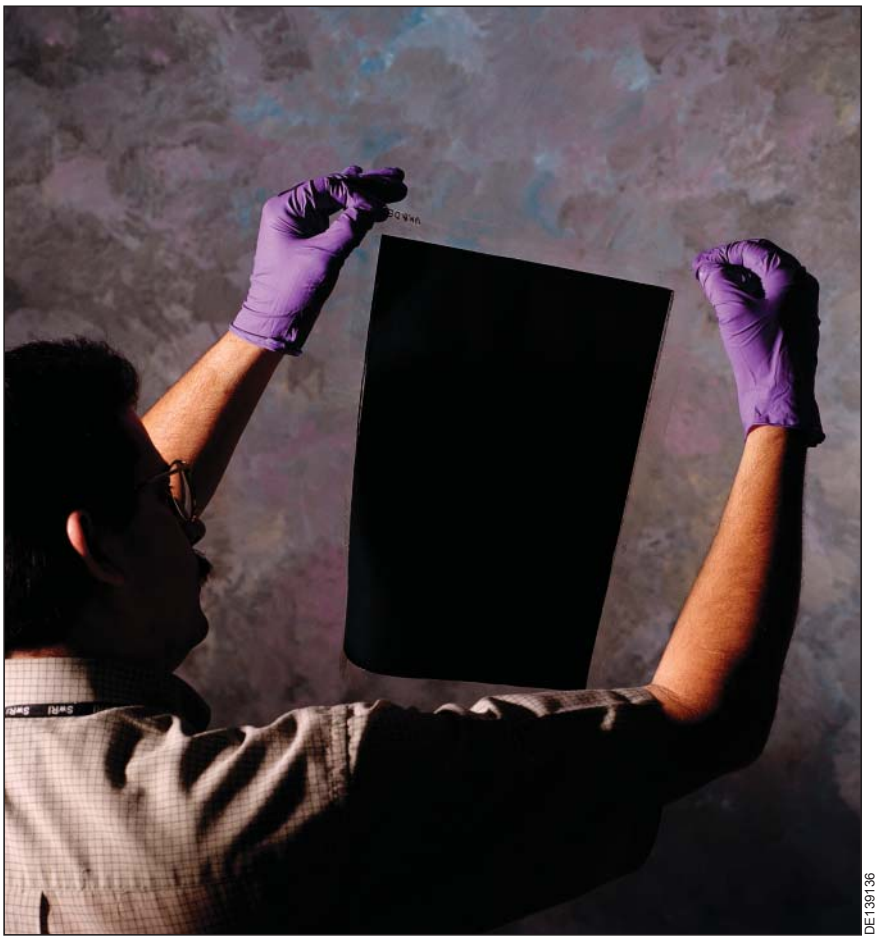
- Proton exchange membrane (PEM) fuel cell electrode assemblies
- Hydrogen storage and separation materials
- Solid oxide fuel cell interconnects, cathodes, and solid electrolytes

Specific areas of effort and interest include:

- Large-area, low-cost vacuum catalyzation methods for PEM fuel cell electrodes
- Novel carbon structures as catalyst supports and hydrogen storage media
- Ultrathin precious metal separation membranes
- Surface-modified ferrous alloys and ceramics to provide improved resistance to oxidation and carbon buildup
- Material property, surface, and interface prediction through molecular simulation
- Electrochemical process modeling

General capabilities related to fuel cell materials include:

- Material specification and selection
- Material characterization
  - Complex dielectric permittivity (temperature dependent)
  - Ionic conductivity (temperature dependent)
  - Electrochemical and impedance behavior
  - Thermodynamic properties
- Membrane electrode assembly (MEA) lay-up and fabrication
- Polymer and organic synthesis
- Ceramic processing

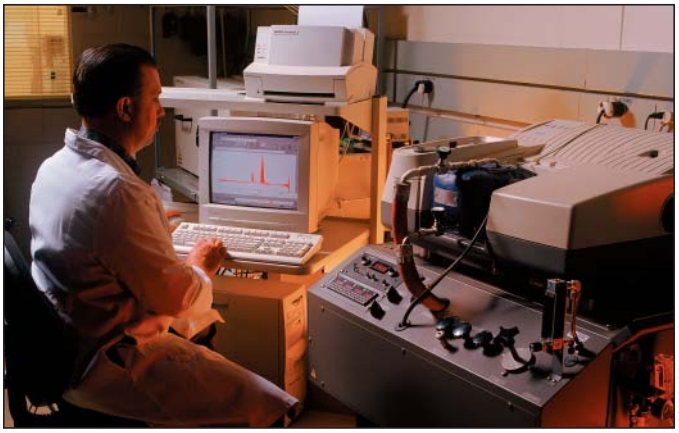


DE139136

SwRI engineers have fabricated 800-square-centimeter active area membrane electrode assemblies, incorporating an ultralow catalyst load electrode technology.

Fuel Processor Testing and Development

The key for many effective fuel cell systems is the fuel processor. Designed to provide the fuel cell with hydrogen for electrical energy production, the processor converts hydrocarbon fuel to hydrogen, producing some waste components. SwRI develops, tests, and validates all aspects of the fuel cell system, including emissions and fuel characterization.



1M139432

Using infrared spectroscopy, Institute engineers evaluate fuel processor performance and system design.

The Institute addresses a wide range of fuel processor components, including:

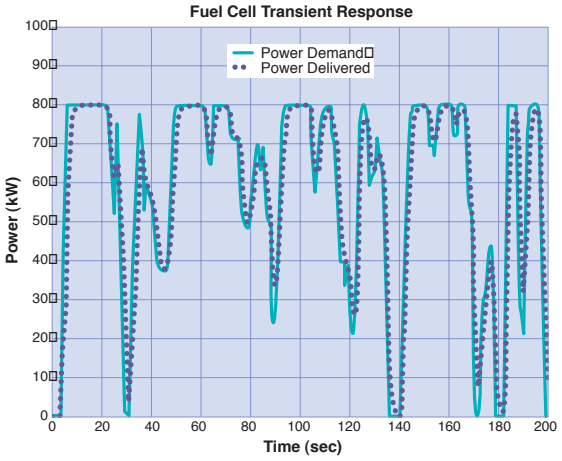
- Fuel vaporizers
- Reformers
- Desulfurizers
- Water-gas shift reactors
- Preferential oxidation catalysts
- System heat exchangers
- Hydrogen purification membranes

SwRI, with more than 60 years of experience in fuel research and testing, provides extensive support in resolving fuel cell problems, such as:

- Reformate constituency, including H_2, CO, CO_2, aldehydes, and sulfur species
- Fuel purity, including CO_2 and sulfur contamination
- Coking
- Catalyst poisoning
- Efficiency evaluation
- Fuel processor start-up performance

Modeling and Optimization

In working with fuel cells, analysis tasks frequently begin with computer modeling of existing systems to determine the energy flow and to size system components. To analyze components and subsystems, SwRI engineers use a variety of sophisticated modeling and simulation tools such as the Institute-developed RAPTOR™. After analyzing the system and conferring with the client, engineers select new or modified components to optimize the system or achieve the client's requirements or performance goals. SwRI may also fabricate and test the system to validate the analytical model and confirm



SwRI engineers model the transient load characteristics under simulated conditions of use.

system performance. As an independent research and development organization, the Institute offers an unbiased perspective on commercial, off-the-shelf equipment and components.

In fuel cell modeling and optimization projects, SwRI staff members use commercial and customized software, including MATLAB™, Simulink™, and EASY5.

SwRI has extensive experience in developing and testing control and diagnostic systems, including:

- Start-up operation
- Dynamic control, emphasizing maximum efficiency or performance
- Energy management and storage systems
- Shut-down characteristics

Systems Development and Integration

The basic no-moving-parts simplicity of fuel cells promises high reliability. In some applications, fuel cells require ancillary equipment such as manifolds, blowers, heat exchangers, humidifiers, condensers, valves, and filters. Each application is unique, requiring careful hardware and software design to achieve optimal performance. For example, stationary fuel cell systems have different design criteria than mobile systems, and specific applications typically have unique equipment goals. SwRI engineers use a systems approach to fuel cell development and integration by first determining the application requirements. Carefully delineating these requirements and goals at the beginning of a project allows Institute engineers to focus on designing and optimizing a system that works for the application.

As part of the SwRI fuel cell integration activities, engineers are developing a fuel cell-powered electric drive system for a Class 8 tractor. The inset illustrates a laboratory setup for a fuel cell-powered auxiliary power unit.

SwRI maintains expertise in the development and integration of the following fuel cell systems:

- Mobile
- Stationary (distributed generation)
- Portable
- Special applications or fuels

With extensive experience in energy production and distribution, the Institute is highly qualified to provide system-level support for fuel cell systems development in the following areas:

- Life expectancy enhancement
- System safety analysis
- Failure mode analysis
- Application integration (heat and power, PEM, solid oxide, alkaline, and phosphoric acid fuel cells)
- Energy-storage development for load-leveling or peak load management
- Power electronics
- System and subsystem control strategies
- System efficiency optimization (minimization of parasitic losses)
- Fuel contamination studies

Test, Measurement, and Characterization

The Institute maintains a multifunctional array of instrumentation and test equipment to support fuel cell development and testing from basic materials to individual fuel cells, stacks, and complete systems. SwRI provides extensive support in testing, measuring, and characterizing hydrogen sources, such as LPG, CNG, methane, propane, and gasoline.

Relevant fuel cell-related testing capabilities include:

- Specialized mechanical testing of gas diffusion media and carbon composite materials
- Creep testing of gasketing and other polymeric components
- High-strain rate testing of ceramic materials
- Stress corrosion cracking evaluation, using multispecimen and single specimen slow strain rate machines, constant deflection systems, and fracture mechanics approaches
- Specialized electromechanical fatigue testing
- Fuel constituent analyses
- Analytical testing, including water content
- Reformate constituency
- Input fuel purity (CO, CO_2, and sulfur contamination)
- Metal hydride and carbon material storage efficiency
- Environmental testing (temperature, vibration, and corrosion)
- Particulate contamination effects
- Stack characterization for power and efficiency
- Biological growth contamination

The Institute also performs bench-scale testing of polymer electrolyte fuel cells and can reconfigure for other types of fuel cells, including direct methanol systems. Specific capabilities include:

- Automated data acquisition and control
- Limited-scale durability testing
- CO and reformate mixing capability
- Cycle polarization and electrochemical impedance testing capabilities

D010988

As part of its material testing capabilities, the Institute maintains six stations for testing individual fuel cells or small stacks up to 1.5 kilowatts.

Manufacturing Systems Technology

Fuel cell manufacturing is still in its infancy, with most systems being produced individually. Fuel cell production entails numerous challenges to the manufacturer, including critical handling issues, contaminant-free environment, and precise component assembly. Effective commercialization of fuel cells requires an efficient, high-volume manufacturing process with high accuracy, repeatability, and good quality control. SwRI has a proven reputation in employing a multidisciplinary engineering approach to develop system solutions.

SwRI conducts a wide range of manufacturing system development programs for a variety of industrial and government clients. Emphasizing process simplification and practical application of technology, SwRI engineers work toward four key objectives:

- Improve resource utilization
- Simplify operational procedures
- Minimize process variability
- Improve product producibility

Using a proven structural approach to system development, SwRI engineers offer a wide variety of services, including:

- Feasibility studies
- Technology assessments
- System definitions of functions, operations, hardware and software
- Special equipment specification
- Detailed hardware design and fabrication
- Turnkey system and facility development
- System integration
- Evaluation and testing
- Control and user interface development
- Operator training
- Maintenance planning and onsite support

1M139151

SwRI developed a pilot-scale manufacturing system for catalyzing practical quantities of PEM fuel cell electrode material under a Department of Energy-sponsored program.

Southwest Research Institute is an independent, nonprofit, applied engineering and physical sciences research and development organization using multidisciplinary approaches to problem solving. The Institute occupies 1,200 acres and provides nearly two million square feet of laboratories, test facilities, workshops, and offices for more than 2,700 employees who perform contract work for industry and government clients.

We welcome your inquiries. For more information, please contact:

Modeling and Systems
Joe Redfield
(210) 522-3729 • Fax (210) 522-5720
E-mail: joe.redfield@swri.org

Materials and Characterization
James H. Arps, Ph.D.
(210) 522-6588 • Fax (210) 522-6220
E-mail: james.arps@swri.org

Fuel Processing and Emissions
Martin J. Heimrich
(210) 522-3022 • Fax (210) 522-3950
E-mail: martin.heimrich@swri.org

Manufacturing
Dan H. Weissling
(210) 522-3535 • Fax (210) 522-4644
E-mail: dan.weissling@swri.org

Southwest Research Institute
6220 Culebra Road • P.O. Drawer 28510
San Antonio, Texas 78228-0510

Web Site: www.swri.org

03-0820-01 1M139106 JCN209479