FUEL CELL POWER

FOR VEHICLES

US Fuel Cell Council

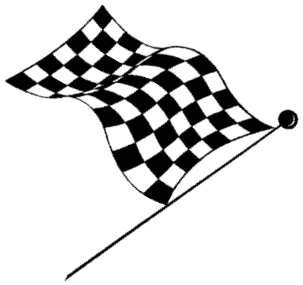
www.usfcc.com

Spring
2001

THE RACE IS ON

The world's leading automakers, fuel cell developers, material and component suppliers, national laboratories and universities are in a race to bring fuel cell vehicles to the marketplace. The goal of this pursuit is to offer an alternative to the internal combustion engine that provides all the performance consumers have come to demand, and at the same time is more efficient and cleaner, increases our fuel diversity, and is ultimately less expensive to manufacture, maintain and operate.

Many of the leaders of this competition are members of the U.S. Fuel Cell Council, the business association dedicated to commercializing fuel cell technology. This report identifies these pioneers, and provides detailed descriptions of their fuel cell vehicle activities. The report concludes with a "Fuel Cell Vehicle Glossary of Terms" that is a valuable tool for understanding this emerging technology.



"All over the world, the auto industry is working in high gear on the fuel cell."
Jürgen E. Schrempp,
DaimlerChrysler Chairman

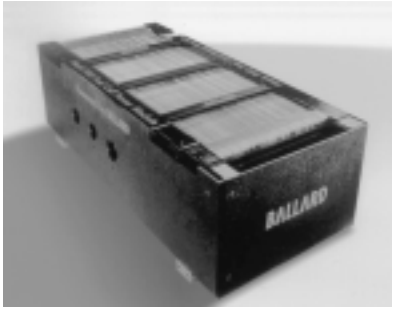
THE FUEL CELL STACK

In 1839, Briton Sir William Robert Grove discovered that hydrogen and oxygen could be combined to produce water and an electric current. In the 1950s, NASA scientists would utilize this discovery to develop fuel cells to power space exploration vehicles. Today, fuel cell technology is being brought back to earth to power everything from cars and buses, to homes and businesses, and even cellular phones and laptop computers.

While there are several different types of fuel cells, proton exchange membrane or "PEM" fuel cells are now found under the hood of most prototype fuel cell cars and buses. The heart of the fuel cell engine is the fuel cell stack. The stack can consist of hundreds of individual PEM fuel cells assembled together to produce enough electricity from the chemical reaction of hydrogen and oxygen to run a car or bus.

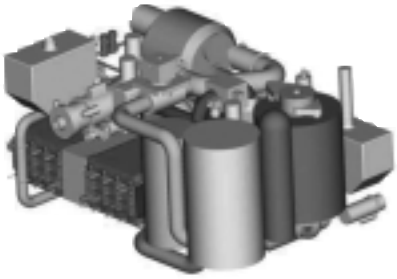
Each PEM fuel cell is a thin wafer with a catalyst-coated membrane resembling a plastic film that is enclosed in graphite or ceramic plates. One side of the membrane acts as an anode, and is fed hydrogen gas. The other side of the membrane serves as the cathode, and is bathed in air to provide oxygen. At the anode, a catalytic reaction takes place and the hydrogen atoms are encouraged to release their electrons and become hydrogen ions (protons). The protons are allowed to diffuse through the membrane to reach the cathode. The electrons are forced to take a different path around the membrane, creating an electric current as they travel to the cathode. At the cathode, another catalytic reaction takes place as the recombined hydrogen atoms join with oxygen to produce water.

Fuel cell stacks with electric capacities of 50 to 75 kilowatts and more are powering prototype passenger cars, minivans, Sport Utility Vehicles, and transit buses. Tremendous improvements in stack efficiency, as well as weight and size reductions, have been achieved in recent years. But more remains to be done. As one automaker has stated, fuel cell technology is "fit for practical use," so the focus has shifted to finding ways to reduce stack costs and preparing for the economies of scale found in mass production.



"I believe fuel cells could end the 100-year reign of the internal combustion engine."
William C. Ford, Jr., Ford Chairman

THE FUEL CELL SYSTEM



The fuel cell stack is just one component of the overall fuel cell system. The system has three basic sub-systems: the fuel processor, the fuel cell stack, and the power conditioner. "Balance of plant" components include pumps, compressors, heat exchangers, motors, controllers and batteries. In many cases, standard "off-the-shelf" components are just not suitable for use in a fuel cell system, and specialized components must be designed and manufactured.

The fuel cell stack utilizes a hydrogen rich gas stream, and there are several approaches to supplying the hydrogen on-board the vehicle. Hydrogen can be stored as a cryogenic liquid at -423°F, held as a gas in pressurized tanks, or contained with metal or chemical hydrides (which employ chemical reactions to store and release hydrogen). Or, the hydrogen can be extracted or "reformed" from liquid fuels such as gasoline, synthetic hydrocarbon fuels, methanol and ethanol, that act as hydrogen carriers. Steam reformers or partial oxidation systems work as small chemical plants on-board the vehicle to convert these liquid fuels into a clean hydrogen gas stream to feed the fuel cell stack.

Fuel cells are direct current (DC) power generators. In some fuel cell vehicle applications the fuel cell's DC power is converted to alternating current (AC) to run AC induction motors, requiring the use of AC motor controllers. In other cases, DC motors are used, governed by DC motor control systems. Much of the of work and resources committed to the development of battery electric vehicle drivetrains in recent decades is being applied to fuel cell vehicle applications.

THE FUEL CELL VEHICLE MARKET

About 60 million new cars are sold worldwide each year. Several automotive industry leaders have speculated that fuel cell vehicles could account for 20 to 25 percent of new car sales within the next 20 to 25 years, a potential market of 12 million to 15 million vehicles each year. Billions of dollars are now being spent by the world's automakers in a race to bring fuel cell vehicles to the marketplace. The first commercial fuel cell vehicle sales are expected as early as 2003/2004. While we may expect these initial sales to involve relatively small numbers of vehicles, by the end of the decade production may increase to millions of vehicles. Economies of manufacturing on this scale are probably necessary for fuel cell vehicles to compete with the sticker price of cars with internal combustion engines under their hoods. Therefore, the initial years of market introduction will be critical to the long-term success of this advanced vehicle technology.

OTHER AUTOMOTIVE APPLICATIONS

Another promising automotive application for fuel cells, in addition to propulsion, is as auxiliary power units or "APUs." Fuel cell APUs are ideally suited to the tractor-trailer truck market. Rather than having a large diesel engine idling during driver rest periods, fuel cell APUs could provide the power for the devices needed for driver comfort, and the diesel engine could be shut down. As the electrical load of today's passenger cars increases, the addition of APUs will help run electric steering, electric brakes, air conditioner compressors, and even televisions and computers. Several fuel cell technologies are being demonstrated for use as APUs, including solid oxide and alkaline fuel cells.

THE FUELING INFRASTRUCTURE

The commercialization of fuel cell vehicles raises a "chicken-and-the-egg" question: Which comes first, the fuel cell cars or the fueling infrastructure necessary to operate them? There are about 200,000 gasoline stations in the United States. Adapting this infrastructure (or some portion of it) to dispense hydrogen or specialized fuel cell fuels likely will require at least some changes. With the first commercial fuel cell vehicles expected to hit dealer showrooms in 2003/2004, it is time to address this question.

Several approaches can be used to deliver hydrogen to a fuel cell vehicle. Natural gas is the feedstock for most industrial hydrogen production. Centrally located hydrogen production plants could produce the necessary hydrogen and distribute it in liquid form to local retail stations for dispensing into fuel cell cars capable of storing either gaseous or liquefied hydrogen. Another option would be to produce the hydrogen locally, by converting natural gas (or possibly other hydrocarbon fuels) into hydrogen gas at the retail station for dispensing to the vehicle. With their central fueling facilities, transit buses are a logical early market for this approach. Finally, promising research is focusing on the use of metal and chemical hydrides.

Alcohol fuels (methanol and ethanol) are excellent hydrogen carriers, and as liquid fuels they are dispensed just like gasoline. There are retail stations across the country currently offering alcohol fuels for use in alternative fuel vehicles capable of running on either gasoline and/or alcohols. While modest capital expenditures are required to convert existing gasoline stations to alcohol operation, there is extensive experience in doing so, and off-the-shelf components are readily available.

The reforming of gasoline on-board a fuel cell vehicle is an option being actively pursued, since the infrastructure is already in place. There would be either minimal or no capital costs required for distribution. We may find that a special blend of gasoline is needed to properly operate a fuel cell vehicle. The sulfur found in gasoline is a particular problem, as it acts as a poison to the catalysts used in fuel cells. The sulfur can be either refined out of the gasoline itself, or removed on-board the vehicle as part of the reforming process. Synthetic hydrocarbon fuels also may play a prominent role in fueling the fuel cell cars of the future.

THE ENVIRONMENTAL BENEFITS

The only emission from the tailpipe of a fuel cell vehicle operating on hydrogen gas is water vapor. Fuel cell vehicles reforming hydrogen carrier fuels on-board will emit only miniscule amounts of the principal pollutants (carbon monoxide, nitrogen oxides and volatile organic compounds) that are regulated by the Clean Air Act. As zero or near zero emission vehicles, fuel cell cars and buses are inherently clean and do not require the elaborate control technologies necessary to maintain the emissions from internal combustion engines.

After a century of constant improvements, the internal combustion engine still only converts on average about 19 percent of the energy in gasoline to turn the car's wheels. Fuel cell vehicles are expected to achieve energy efficiencies of 40 to 45 percent. Given this significant improvement in energy efficiency, fuel cell vehicles offer substantial reductions in greenhouse gas emissions, and higher mileage too.

THE U.S. FUEL CELL COUNCIL

The U.S. Fuel Cell Council is the industry association for all those seeking to foster the commercialization of fuel cells in the United States. Our membership includes producers of all types of fuel cells, as well as major suppliers and customers. Formed in 1998, the U.S. Fuel Cell Council is organized as a nonprofit [501(c)(6)] organization.

The Council provides its members an opportunity to develop policies and conduct education and outreach activities for the fuel cell industry, and also gives every member the chance to benefit from one-on-one interaction with colleagues and opinion leaders important to the industry. Members have access to exclusive reports and analyses prepared by the Council, and to the "members only" section of our web site.

The Council is member driven. A Board of Directors made up of all Executive Members sets budgets, policies and direction. Programs are carried out by Working Groups which are open to Executive and Associate Members. A Policy Committee provides oversight. Active Working Groups include: Codes & Standards; Transportation; Power Generation; Portable Power; and Education & Outreach.

Working Groups

The Codes & Standards Working Group makes itself aware of all relevant codes and standards activities, gathers information from all possible sources, and provides information to the members of the Council and encourages participation and commentary by member companies. The Codes & Standards Working Group serves as the communication conduit for member commentary on codes and standards at the local, regional, national, and international levels.

The Education & Outreach Working Group helps accelerate the commercialization of fuel cell technologies by developing education and outreach tools, identifying critical audiences that can support market introduction, disseminating key messages to targeted audiences, supporting the work of the other USFCC Working Groups, and assisting with USFCC membership recruitment.

The Portable Power Working Group promotes the commercialization of portable fuel cell power systems by identifying key markets, making potential users and their agents aware of fuel cell power source devices and their capabilities, removing barriers to deployment, transportation and use, and encouraging demonstration programs to promote acceptance and successful commercialization.

The Power Generation Working Group promotes the use of fuel cells in large power generation applications, small distributed systems, and power generation systems on-board mobile platforms by providing market characterization studies, feasibility studies, and other supporting resources to the members.

The Transportation Working Group promotes the use of fuel cells for transportation systems by developing reports, analyses, policy statements, and other materials. The Working Group also provides leadership for fuel cell vehicle standards development activities.

For additional information about the U.S. Fuel Cell Council, visit our web site at www.usfcc.com, or call us at (202) 293-5500.

PROTOTYPE FUEL CELL VEHICLE INTRODUCTION

Automaker	Vehicle Type	Year Shown	Fuel Type
BMW	Series 7 Sedan	In development	hydrogen
DaimlerChrysler	NECAR (van)	1993	gaseous hydrogen
	NECAR 2 (mini-van)	1995	gaseous hydrogen
	NECAR 3	1997	liquid methanol
	NECAR 4	1999	liquid hydrogen
	Jeep Commander 2 (SUV)	2000	methanol
	NECAR 5	2000	methanol
	DMFC (One-Person Vehicle)	2000	methanol
Energy Partners	Green Car (Sports Car)	1993	hydrogen
Ford Motor Company	P2000 HFC (sedan)	1999	hydrogen
	P2000 SUV	1999 (concept only)	methanol
	TH!NK FC5	2000	methanol
General Motors/Opel	Zafira (mini-van)	1998	methanol
	Precept	2000	hydrogen
	HydroGen1	2000	hydrogen
Honda	FCX-V1	1999	hydrogen
	FCX-V2	1999	methanol
	FCX-V3	2000	hydrogen
H Power	New Jersey Venturer	1999	hydrogen
	New Jersey Genesis	2000	hydrogen (from sodium borate or "Borax")
Hyundai	Santa Fe (SUV)	2000	hydrogen
Mazda	Demio	1997	hydrogen (stored in a metal hydride)
Nissan	R'nessa (SUV)	1999	methanol
	Xterra (SUV)	2000	methanol
Renault	FEVER (station wagon)	1997	liquid hydrogen
	Laguna Estate	1998	liquid hydrogen
Toyota	RAV 4 FCEV (SUV)	1996	hydrogen (stored in a metal hydride)
	RAV 4 FCEV (SUV)	1997	methanol
Volkswagon/Volvo	Bora HyMotion	1999	hydrogen

Source: Breakthrough Technologies Institute

California FUEL CELL PARTNERSHIP

DRIVING FOR THE FUTURE

AMERICAN METHANOL INSTITUTE

www.methanol.org

The world's automakers consider methanol to be a leading hydrogen carrier candidate for powering fuel cell vehicles. Methanol, a liquid fuel made from natural gas or renewable resources, has been the fuel of choice for INDY 500 race cars for more than 30 years, and has fueled thousands of flexible fuel vehicles that use either methanol or gasoline in an internal combustion engine. Methanol is now being used in prototype fuel cell cars built by DaimlerChrysler, Ford, General Motors, Toyota, Nissan, Honda, Volvo and Volkswagen. In addition, fuel cell buses developed by Georgetown University are filling up with methanol.

There are 18 methanol production plants in the United States with a combined annual capacity of more than 2.6 billion gallons. Worldwide, over 90 methanol plants combine for a total annual capacity of more than 11 billion gallons. The global methanol industry generates $12 billion in economic activity each year while creating nearly 100,000 jobs.

At the pump, methanol should be a bargain. In California, the retail pump price for methanol ranges from $0.84 to $1.10 per gallon. Even after adjusting for methanol's lower energy content, highly efficient methanol fuel cell vehicles will be very competitive with gasoline-powered vehicles. The capital cost for adding methanol capacity to an existing gasoline station is about $62,000.

"The global methanol industry is ready, willing and able to serve a worldwide market for fuel cell vehicles," states American Methanol Institute president & CEO John Lynn. "AMI estimates show that for about a $3 billion investment, methanol pumps could be added to one out of every three corner 'energy' stations in the country. This certainly beats the $13 billion in capital costs spent to produce the reformulated gasoline sold in one-third of the nation."

ATOFINA CHEMICALS, INC.

www.ato.com

ATOFINA Chemicals, Inc. has more than 30 years' experience in designing and manufacturing high-purity polymers for special high-technology applications such as fuel cells. The company's KYNAR® PVDF fuel cell-grade polymers are well suited for proton exchange membranes, molded bi-polar plates, and conductive coatings for bi-polar plates. Some of the applications for fuel cells using KYNAR polymer technology are power generation, transportation, electronic devices, aerospace, computers and marine.

KYNAR PVDF is an excellent material for fuel cell applications because it can be used to make fuel cells lighter, and/or to lower manufacturing costs. KYNAR polymers exhibit outstanding mechanical strength, high thermal stability, high dielectric strength, high purity, and exceptional resistance to most chemicals and solvents.

For those fuel cell research, development, and manufacturing companies also interested in battery projects, KYNAR PVDF polymers are also available in battery-grades. They exhibit the same performance properties and processing characteristics as KYNAR PVDF fuel cell-grade polymers and are designed for use as binders for cathodes and anodes in lithium-ion technology, and as battery separators in lithium-ion polymer technology.

Copies of ATOFINA's Fuel Cell Newsletter, "KYNAR KONCEPTS," are available upon request. Also available are copies of the presentation, "ATOFINA Presents KYNAR® PVDF Polymers for Fuel Cell Applications" on CD-ROM or printed copy. Contact Joseph Carey at 800-486-2110 or 215-419-7523, or by fax at 215-419-7497. ATOFINA produces high-performance chemicals and polymers that offer solutions for many markets and applications. ATOFINA has sales of $1.8 billion and employs 3900 people in North America and 1000 people internationally.

BALLARD POWER SYSTEMS

www.ballard.com

Ballard is recognized as the world leader in proton exchange membrane (PEM) fuel cell technology. Its principal business is the development and commercialization of PEM fuel cells and fuel cell systems for use in selected power generation applications, including transportation, small to mid-sized stationary power generation and portable power use. Ballard has been developing PEM fuel cells and PEM fuel cell systems for 17 years, and this has been the company's primary business since 1989.

In the transportation market, Ballard has formed a vehicular alliance with DaimlerChrysler and Ford. Together with our alliance partners, Ballard formed XCELLSIS, to develop and commercialize PEM fuel cell systems for cars, buses and trucks, and Ecostar, to develop and commercialize electric drive trains.

Success in the development of Ballard® fuel cells and PEM fuel cell systems has enabled the company to deliver Ballard® fuel cells and PEM fuel cell systems to original equipment manufacturers and other customers for testing and demonstration in cars and buses, stationary power generators and portable power generators. Ballard's partners and customers have used Ballard® fuel cells to power 10 transit buses, six of which have been used in revenue service, and nine prototype cars, most recently Ford's TH!NK FC5 which was unveiled in January 2000, and DaimlerChrylser's NECAR5 which was unveiled in November 2000. Other automobile manufacturers have also used Ballard® fuel cells in their prototype PEM fuel cell powered cars.

Through the California Fuel Cell Partnership, Ballard is working with other organizations, including the State of California, the U.S. Department of Energy, DaimlerChrysler, Ford, Honda, Nissan, Volkswagen and Shell, Texaco and ARCO, to test and demonstrate more than 70 fuel cell powered cars and buses in California between 2000 and 2003, while also addressing fuel infrastructure issues.

Ballard is moving rapidly closer to the introduction of its first commercial products. With its introduction, Ballard will begin to turn its vision - Power to Change the World™ - into a reality.

CALIFORNIA AIR RESOURCES BOARD

www.arb.ca.gov

The California Air Resources Board (CARB) is a division of the California Environmental Protection Agency. The mission of the California Air Resources Board is to promote and protect public health, welfare and ecological resources through the effective and efficient reduction of air pollutants while recognizing and considering the effects on the economy of the state. Two of CARB's key regulatory responsibilities are establishing motor vehicle emissions standards and fuel specifications for the state. Fuel cell vehicles offer the potential to meet the California Air Resources Board's zero emission vehicle regulation.

CARB is one of the founding members of The California Fuel Cell Partnership (The Partnership). The Partnership represents the first time that government entities and competing companies have joined together to demonstrate fuel cell vehicles and their fuel infrastructure under real day-to-day driving conditions. The collection of members represents worldwide interest in fuel cell vehicle technology. The Partnership includes auto manufacturers, energy providers, technology companies, and government agencies.

Urban transit buses represent another promising opportunity for the use of fuel cells, and particularly fuel cells utilizing on-board hydrogen. CARB supports the use of hydrogen in zero emissions buses in two programs: (1) the Zero Emission Bus (ZEBus) requirements of the 2000 Transit Bus Regulations and (2) the California Fuel Cell Partnership's Bus program. Transit Bus ZEBus regulations require 15% of fleet purchases to be ZEBus purchases beginning as early as 2008. Fleets with over 200 buses that primarily use diesel fuel will be required to demonstrate ZEBs in 2003. The Partnership will place up to 20 hydrogen fuel cell buses in California transit agencies by the end of 2003.

DaimlerChrysler

DAIMLERCHRYSLER

www.daimlerchrysler.com

DaimlerChrysler is the world leader in building, driving and testing vehicles that demonstrate the most advanced fuel cell technology. The company is committed to marketing the first fuel cell city buses in 2002, and fuel cell-powered cars in 2004. DaimlerChrysler will invest more than $1.4 billion to develop fuel cell technology over the next four years.

In 2000, DaimlerChrysler unveiled two new concept vehicles demonstrating the most advanced fuel cell powertrains: The NECAR 5 (for New Electric Car), the fifth generation of fuel cell vehicle put on the road by DaimlerChrysler, is a methanol-fueled passenger car; The Jeep Commander 2 uses a methanol reforming fuel cell and battery hybrid powertrain in a large, luxury, four-wheel-drive sport utility vehicle. The first Jeep Commander, unveiled in 1999, incorporated an onboard reformer to produce hydrogen from gasoline for the fuel cell stacks.

DaimlerChrysler unveiled its first fuel cell vehicle in 1994, the NECAR 1, a hydrogen-fueled fuel cell mini-bus. The NECAR 2 in 1996 used a hydrogen-fueled fuel cell powertrain in a Mercedes-Benz V-class van. In 1997, DaimlerChrysler presented the first fuel cell powered bus, the NEBUS, which also used compressed hydrogen as the fuel.

The NECAR 3, also unveiled in 1997, was the world's first fuel cell car fueled by methanol. And in 1999, DaimlerChrysler unveiled the NECAR 4, a Mercedes-Benz A-class compact car using liquid hydrogen fuel to achieve a 280 mile range, and a top speed of 90 miles per hour in a zero emission vehicle.

In the development of fuel cell-powered vehicles, DaimlerChrysler works closely with its partners, Ballard Power Systems which produces fuel cell stacks, and XCELLSIS, which builds the fuel cell engines for automobile powertrains. To encourage development and commercialization of fuel cell vehicles, DaimlerChrysler was a founding member of the California Fuel Cell Partnership.

dmc²
Degussa Metals Catalysts Cerdec

dmc² (DEGUSSA METALS CATALYSTS CERDEC)

www.dmc-2.com

One of the world's largest suppliers of emission control catalysts, dmc² is moving ahead with fuel cell products designed to support the operation of proton exchange membrane (PEM) fuel cell systems. Proven technology such as the pMembrain™electrode assembly is scheduled for automated pilot production during 2001 at a dmc² facility in Germany. This proprietary membrane electrode assembly (MEA) has been designed to meet the specifications of various fuel cell stack sizes, shapes and operating parameters.

The heart of the fuel cell stack, MEAs must perform efficiently at high and low current densities for extended lifetimes. dmc² supplies MEAs to the fuel cell marketplace now and is preparing for growing market demand in the years ahead based on a demonstrated ability to provide reliable, cost-effective MEA technology.

Expert in a wide range of catalysis processes, coating technologies and precious metal chemistry and management, dmc² offers fuel cell makers and OEMs a complete set of catalysts needed for compatibility among components within a fuel cell system. In addition to the pMembrain™MEA, this includes the the protonics™ family of fuel processing catalysts and the elyst™platinum-ruthenium electrocatalyst, a CO-tolerant anode for fuel cells engineered for reformate fuel.

Fifteen years of experience with fuel cells has provided dmc² with the insight necessary to tailor components to OEM systems in a minimum of time. Today, dmc² is engineering key components simultaneously with customers and actively supporting the emerging commercial-scale production of fuel cells.

More than 5000 dmc² employees worldwide are dedicated to the design and manufacture of products that contribute to energy technology, coatings technology, electronics technology and environmental protection. dmc²'s integrated global supply chain and 100-year history of technological advancements is at your command.

DELPHI AUTOMOTIVE SYSTEMS

www.delphiauto.com

Delphi Automotive Systems is working with BMW and Renault to develop solid-oxide fuel cell (SOFC) technology as an auxiliary power source for cars and trucks. Vehicles using these fuel cells will be powered by conventional internal combustion engines.

A memorandum of understanding among the companies expands the existing development agreement between Delphi and BMW, signed in April, 1999, under which they are jointly developing a fuel-cell system as an auxiliary power source for gasoline engines. This expansion focuses on the development of diesel-fuel solid-oxide fuel cell reformers for Renault light- and heavy-duty trucks.

Delphi will work with Renault and BMW to use the SOFC as an auxiliary power unit (APU), which will increase the total availability of electrical power on-board the vehicle. Unlike a battery, the APU will be able to provide indefinitely for electrical accessories as long as there is fuel in the tank.

A major benefit of the SOFC -- compared to the proton exchange membrane fuel cell that is being adopted for traction applications -- is that the SOFC is much less sensitive to impurities in commercial-grade fuel and carbon monoxide.

"Delphi is also developing a PEM fuel cell for traction applications. But the SOFC is more attractive as an APU because of its efficiency and because it does not require a cumbersome reforming process to run using current fuels," said Jean Botti, director of the Customer Solution Center at Delphi Energy & Chassis Systems.

Delphi is also working on complementary technologies that could be combined with the SOFC to further increase powertrain efficiency. "We see terrific long-term potential for the SOFC as part of an integrated powertrain strategy," Botti said.

DONALDSON COMPANY, INC.

www.donaldson.com

Donaldson Company, Inc. develops and manufactures particle filtration, chemical adsorption, and exhaust systems that help protect everything from equipment and engines to people and the environment. For more than 85 years, the company has perfected and leveraged its core strengths - technology, client relationships and a global presence - to meet the diverse and changing needs of its customers and to grow and strengthen their business.

Donaldson's innovative filtration solutions apply to a wide array of products and operating environments, including: air and liquid filters and exhaust and emission control products for mobile equipment; industrial air cleaning systems; intake and exhaust products for industrial gas turbines; aircraft and automobile passenger cabins; and specialized particle and chemical filters for highly sensitive environments like computer disk drives, cleanrooms, and semiconductor processing.

Once again Donaldson takes the lead in the development of filtration solutions for both low and high temperature fuel cells, in the form of pollution abatement filters. They have assembled the most comprehensive technical filtration resources dedicated to fuel cell applications in the world. This focused fuel cell team is backed by a broad range of corporate resources in product test and evaluation, analytic chemistry, structural and flow modeling on a dedicated supercomputer, and advanced manufacturing methods.

Every day, employees at Donaldson are exploring ways to help solve customer problems and apply technology to new markets such as fuel cells. Their technological leadership, combined with strong client relationships and a global presence, will keep Donaldson at the forefront of these markets for years to come.

Some of Donaldson's well-known global customers include: Caterpillar, General Electric, Daimler-Chrysler, John Deere, Intel, Boeing, Mitsubishi, General Motors, Hyundai, Volvo, Isuzu, Scania, Ford, Saab, General Dynamics, Renault, Komatsu, Freightliner, IBM, and Seagate, among others.

DOW CORNING

DOW CORNING CORPORATION

www.dowcorning.com

Dow Corning has provided the silicone materials of choice for fuel cell applications since the early days of the U.S. Space Program. Dow Corning silicone based materials have been used in fuel cell sealing, hoses and other uses on much of the specialty, prototype and demonstration work over the last few years.

Through a globally linked development program Dow Corning is focused on providing the best value in place solutions for our fuel cell industry customers. The fuel cell program at Dow Corning is coordinated by the Transportation, Energy and Fabrication Industries business unit.

Dow Corning expects to continue as the leader in providing silicone based materials for the best value in place solutions for fuel cell vehicles. Through strategic partnerships with lead developers in the fuel cell vehicle industry its working on sealing, hoses and other uses for silicone based materials. Dow's broad technical knowledge and application background is the advantage it gives to these partnerships to bring new technology into manufacturing reality for fuel cell stacks and balance of plant applications.

Dow Corning believes that providing the preferred material solutions for its customers in the fuel cell vehicle industry is a natural fit with its vision - "Technology Leads - Service Wins."

energy partners

ENERGY PARTNERS

www.energypartners.org

Founded in 1990, Energy Partners is a leader in the research and development of proton exchange membrane (PEM) fuel cells. Over the years, Energy Partners has developed a rich history in systems integration and a wealth of experience using PEM fuel cells for transportation. Energy Partners' accomplishments include demonstrating stack power densities as high as 600W/L and significantly reducing the overall cost of fuel cell stacks with the introduction of an advanced molding technology for bipolar plates.

EP's most recent automotive success was at the 1999 Future Car Challenge. Energy Partners supplied Virginia Tech University with a 20 kW fuel cell stack that was installed in a hybrid electric car. Virginia Tech's Chevy Lumina took first place in the lowest-emissions category and held second place overall.

In a 1996 collaborative effort with Deere and Company, Energy Partners converted two John Deere Gator™ utility vehicles to fuel cell power. Each vehicle is powered by a 10 kW fuel cell stack and is equipped with an 115V inverter with standard electrical outlets. The "Gators" are currently being retrofitted with advanced fuel cell stacks and metal hydride fuel storage beds.

Energy Partners had its beginning in transportation applications with the "Green Car." Completed in 1993, this hybrid proof-of-concept car was powered by three 5 kW fuel cell stacks with the intention of impacting world pollution. In 1995, Western Golf Car and Energy Partners jointly developed the Genesis Zero Emission Transporter. The 7.5 kW "Genesis" comfortably carries eight passengers for up to three hours. Recently, Energy Partners' reputation of excellence has earned it a contract with the U.S. Department of Energy to develop an automotive fuel cell system that is cost effective and capable of running on a standard automotive fuel.

Energy Partners is currently focusing the knowledge and experience gained from its transportation achievements on the commercialization of stationary fuel cell systems. With a strong technological background in stack development and systems integration, Energy Partners is certain to become a leader in the residential and small commercial markets.

EXERGY, INC.

www.exergyinc.com

Exergy Incorporated, founded in 1979, has provided its expertise on miniature, high performance heat exchangers to many of the leading developers of fuel cells for transportation. Very early on, the lightweight, compactness and high performance of Exergy's heat exchangers were recognized to be an excellent match for fuel cell applications in the transportation sector.

Exergy expertise in the design, application, and manufacture of miniature heat exchangers provides an excellent solution to many of the heat transfer needs of those involved in the research, development and manufacture of fuel cell systems for the transportation industry. Working with most of the leading players in the fuel cell transportation sector, Exergy has performed heat transfer application studies and provided standard products or designed highly customized products to successfully meet the transportation sector fuel cell heat transfer requirements.

Exergy views the future market for its products and services to be extraordinary, as the development and commercialization of transportation sector fuel cell systems unfold in the next few years. Exergy's responsiveness and its ability to successfully size its product line to meet the unique heat transfer requirements of the fuel cell builders gives Exergy confidence that it will continue to be a valued supplier to the fuel cell industry as the commercialization of transportation sector fuel cell emerges over the next 5 to 10 years.

Exergy expects the fuel cell to be a major factor in the near future, as the transportation industry addresses the economic and environmental issues with which we are currently struggling within our petroleum fuel based transportation economy.

FORD MOTOR COMPANY - TH!NK GROUP

www.ford.com

Ford Motor Company introduced the world's first production-prototype, direct-hydrogen powered fuel cell vehicle in November 2000. Based on Ford's popular Focus platform, the Focus FCV brings high-tech and high volume together for the first time by combining the world's most advanced powertrain with the world's best selling passenger car.

The Ford Focus FCV showcases the company's continuing effort toward production of full performance fuel cell vehicles that offer customers a seamless, no-compromise experience. Ford is committed to offering fuel cell vehicles to customers by 2004.

The Focus FCV combines high fuel economy, performance and comfort with desirable electric vehicle attributes such as improved noise, vibration and harshness (NVH) and zero emissions.

The Focus FCV has a direct hydrogen powertrain configuration. Ecostar Electric Drive Systems and XCELLSIS supply the electric motor and fuel cell engine respectively. The heart of the fuel cell system is a Mark 900 series proton exchange membrane (PEM) fuel cell stack module from Ballard Power Systems.

The Focus FCV is the second direct hydrogen powered fuel cell vehicle from Ford. The company introduced its first fuel cell vehicle - the P2000 HFC - at the North American International Auto Show in Detroit in January 1998.

EXERGY INCORPORATED

Ford

THINK is a trademark of Ford

FREUDENBERG-NOK

www.fngp.com

With seals being crucial to the efficiency and cost of the next generation of fuel cells, seal technology expert Freudenberg-NOK and its global partners are working on a number of development projects with fuel cell manufacturers to advance the technology.

By applying its unmatched 100-year heritage of seal design expertise, its lean manufacturing culture, its state-of-the-art analytical tools, and a global team to fuel cell applications, Freudenberg-NOK is designing integrated components, manifolds, seals, high-temperature gaskets and o-rings for fuel cells which can help to dramatically reduce assembly cost, improve packaging and increase the efficiency of the next generation of fuel cells.

Long a technology leader in automotive and industrial sealing, Freudenberg-NOK - based in Plymouth, Michigan - offers its customers globally integrated sealing packages for transmissions, engines, brakes, axles and steering; vibration control components and packages; and precision molded components for suspension, electrical and fuel systems. The company also offers an extensive portfolio of precision molded seals and products for the aerospace, appliance, business machine, fluid power, marine, medical, off-highway and recreational vehicle markets.

Freudenberg-NOK is part of the Freudenberg and NOK Group, which has total annual sales of nearly $7 billion and global automotive sales of $4 billion. The Freudenberg and NOK Group was listed by Crain's *Detroit Business* as the 15th largest OEM automotive supplier and is one of only eight in the top 100 suppliers that has global balance in each of the three major automotive markets -- Asia, Europe and North America -- according to *Automotive News*.

HYDROGEN BURNER TECHNOLOGY, INC. (HBT)

www.hydrogenburner.com

Hydrogen, the most abundant element in the universe, is rapidly developing into the clean fuel of choice for the new millennium. Although abundant, hydrogen must be derived from fuels such as natural gas, propane, methanol or gasoline. The key to the commercial success of fuel cell technology is the process of economical and reliable hydrogen generation.

"The full potential of fuel cell systems can only be realized with the successful development of low cost, high reliability, multi-fuel fuel processors," states David Moard, president of HBT. "With our patented technology, HBT is a leader in the development of fuel processor technologies for the stationary, mobile and industrial markets."

Phoenix Gas Systems, a division of Hydrogen Burner Technology, Inc. (HBT) has introduced a new skid-mounted system designed for on-site hydrogen generation. The unit operates on the patented Under-Oxidized Burner (UOB©) process, which converts hydrocarbon fuel into hydrogen using high temperature combustion in an oxygen-lean environment.

In the near future, its PGS Hydrogen Generation Systems will be used as part of a Hydrogen Refueling Station. They are being coupled with compression, storage and delivery systems to provide the high purity hydrogen required for direct hydrogen fuel cell vehicles.

Another division of HBT, Phoenix Fuel Cell Systems, is developing products for fuel cell vehicles to enable the wide spread introduction of fuel cell vehicles into the marketplace by capitalizing on the existing transportation fuels infrastructure. With the cost of creating a hydrogen refueling infrastructure estimated in billions of dollars, the most economical way to bring fuel cell vehicles to market may be to create hydrogen on board the vehicle from fuels such as gasoline and diesel.

IMPCO TECHNOLOGIES, INC.

www.impco.ws

IMPCO is the leading designer, manufacturer, and supplier of enabling technology for advanced fuel storage, fuel delivery, and electronic control systems that allow internal combustion engines, micro-turbines and fuel cells to operate using clean fuels such as hydrogen, propane and natural gas. IMPCO designs these systems to optimize the efficiency and performance by electronically sensing and regulating the proper proportion of fuel and air used. IMPCO supplies these products to original equipment manufacturers of motor vehicles, buses, trucks, forklifts, and small portable to large stationary engines.

Our products are based on proprietary and patented technology. Key IMPCO technologies for fuel cell vehicles include the following: development of a commercially viable high performance hydrogen storage cylinder with 7.5% hydrogen storage by weight; development of an 8.5% hydrogen by weight storage technology in early 2001 with commercialization to commence thereafter; patent for a 5000 psi crash resistant in-tank regulator for hydrogen, the "H2R 5000"; development, integration, and installation of an advanced hydrogen fuel storage and fuel delivery system for Hyundai Motor Company's new fuel cell prototype Santa Fe Sport Utility Vehicle.

IMPCO combines proprietary designs, software, and calibration tools to develop, calibrate, and optimize power train control systems. IMPCO provides service capabilities in the areas of development, validation, certification, manufacture, and service support. Our customers use these capabilities to support their programs in the transportation sector, material handling, power generation applications, and fuel cell vehicles.

IMPCO continues to pursue further advances in storage technology, materials, regulators, metering, sensors, controllers, and refueling infrastructure that will enable fuel cell vehicles to become transparent to the consumer and end user of today's gasoline engine-powered automobiles.

INTERNATIONAL FUEL CELLS

www.ifc.com

International Fuel Cells (IFC) is the world leader in the production and development of fuel cell power plants for transportation, stationary, residential and space applications. IFC has been a supplier of fuel cell power plants since 1961. It has produced and delivered more than 500 power plants. Two hundred of these, delivered for commercial power generation on four continents, have accumulated more than 3,600,000 hours of operation. IFC has been developing Proton Exchange Membrane (PEM) fuel cells for transportation since 1987.

Today, IFC is supplying PEM power plants for traction and auxiliary power. Vehicle and laboratory evaluations are in progress. Ford Motor Company, BMW, Volkswagen, Hyundai, other OEMs and the U.S. Department of Energy have received or are working with IFC to develop automotive power plants. Thor Industries, IRISBUS and NOVABus (Volvo) have received or are working with IFC to develop commercial vehicle power plants. IFC power plants used in these activities are fueled with hydrogen, gasoline or methanol.

The auxiliary power units (APUs) IFC supplies significantly increase the onboard electrical power above that possible with conventional vehicle power supply systems. Increased electric power enables new and broader environmental comforts for driver and passengers and expanded electronic and computer capability for communication and safety. BMW first demonstrated the APU's benefit in a Series 7 vehicle at the Frankfurt Auto Show and is expanding the demonstration as part of its EXPO 2000 program.

IFC foresees broad application of fuel cell technology in transportation markets. Fuel cells will enable greater driver and passenger comfort and safety, improved fuel economy, reduction and eventual elimination of emissions and greenhouse gases and introduction of new and renewable fuels.

JOHNSON MATTHEY FUEL CELLS

www.matthey.com

Johnson Matthey has committed years of effort to developing fuel cell materials, which began with the optimization of platinum catalysts. Since then, Johnson Matthey's expertise has grown to encompass all the catalyzed components of a fuel cell system, including specialist catalysts, electrode manufacture, MEA design and production, fuel processor system and subsystem design and manufacture.

Johnson Matthey Fuel Cells is working closely with key players in the automotive sector of the fuel cell industry, including Ballard, International Fuel Cells, XCELLSIS, Aisin, General Motors, Volvo, VW and Fiat, to develop fuel cell stack and fuel processor components.

Johnson Matthey Fuel Cells is a world leader in fuel cell catalysts, and manufactures a range of catalysts designed to give optimum performance in PEM and direct methanol fuel cells. The HiSPEC™ range consists of single and bimetallic supported and unsupported catalysts, which have been used with success on both anodes and cathodes.

Through its agreement with Technical Fibre Products (TFP), the advanced composites subsidiary of James Cropper PLC, Johnson Matthey Fuel Cells is developing carbon composite substrates used to support the catalysts and other active components within an MEA. The agreement brings together Johnson Matthey's strong catalyst technology and intellectual property in the field of fuel cells and MEAs and James Cropper's experience in the volume manufacturing of advanced technical non-woven materials.

Johnson Matthey Fuel Cells' Gas Processing Technology is developing HotSpot™ reformers, Demonox™ gas cleanup units, catalytic combustors and reformer emission control units. Johnson Matthey Fuel Cells has an exclusive supply and development agreement with XCELLSIS to supply the catalytic parts of the reformate cleanup system for their fuel cell engines.

The HotSpot™ system is being developed to reform fuels such as methanol, natural gas, LPG and higher hydrocarbons, including gasoline. This technology was awarded the prestigious Italgas Award for Technology in 1999.

MCDERMOTT TECHNOLOGY, INC.

www.mtiresearch.com

McDermott Technology, Inc. (MTI) is developing a family of fuel processors for solid-state fuel cells operating on a wide range of fuels. MTI began developing fuel processors in the early 1990's as an outgrowth of its solid oxide fuel cell development program. Fuel processor development at MTI quickly became a significant program in its own right.

Since 1994, MTI has reformed many fuels, including natural gas, gasoline and diesel fuel. Noncatalytic, partial-oxidation, catalytic autothermal, and steam reforming have all been employed. MTI has developed special expertise in distillate fuel processing, which is being applied to the development of a 500 kW autothermal fuel processor for use in marine applications. MTI is also developing a 50 kW multifuel processor for fuel cell electric vehicles.

In 1998, MTI teamed with Ballard Power Systems and Gibbs & Cox to develop a PEM fuel cell generator for Navy ship-service power. Phase I produced a system conceptual design of a 2.5 MW, ship-service fuel cell and demonstrated critical components under military marine conditions. MTI won a follow-up contract for design and delivery of a prototype 500 kW integrated fuel processing system.

In 1999, the U.S. Department of Energy selected an MTI-lead team to develop a fully integrated 50 kW catalytic multifuel processor suitable for automotive applications. The team developed a proprietary design that incorporates advanced, state-of-the-art reforming, liquid-phase desulfurization, and CO clean-up to achieve compact size, simplified controls, and high efficiency.

In 1997, under contract with the Defense Advanced Research Programs Agency and the Army Research Office, MTI completed a successful 300-hour demonstration of a proprietary, 50 kW, JP-8 fuel processor integrated with a planar solid oxide fuel cell achieving greater than 70% conversion efficiency.

METHANEX

www.methanex.com

Methanex is a leading global manufacturer and distributor of methanol with plants located in North America, Chile and New Zealand. Its extensive global marketing and distribution system has made Methanex the largest supplier of methanol to each of the major international markets, and its sales accounted for roughly 24% of the total world market for methanol in 1999.

Methanol is widely considered to be a leading candidate as the fuel of choice for vehicular fuel cell applications. Methanol is primarily produced from natural gas, a widely acknowledged clean source of energy. Although the world has vast reserves of natural gas, they are remotely located outside major energy-consuming regions. Methanex believes that the most practical solution to the fuel cell infrastructure challenge is by providing a readily transportable, environmentally friendly hydrogen carrier, such as methanol.

In 2000, Methanex joined the California Fuel Cell Partnership as an associate member. Its role in the partnership is to demonstrate the viability of methanol fuel infrastructure technology, develop appropriate fuel composition standards, and assist in developing a path to commercializing fuel cell electric vehicles.

Also, in September of 2000, Methanex entered into cooperative efforts with industry leaders to evaluate what would be needed to facilitate the introduction and commercialization of methanol fuel cell vehicles. This effort, which includes BASF, BP International, DaimlerChrysler, Statoil and XCELLSIS, will examine any health, safety, environmental and infrastructure issues associated with the mass introduction of methanol fuel cell vehicles.

In addition, Methanex has interacted extensively with fuel cell, automotive and stationary power industry stakeholders providing technical information regarding methanol as a fuel for fuel cell applications.

METHANEX®

A Responsible Care® Company

NEXTECH MATERIALS, LTD.

www.nextechmaterials.com **www.fuelcellmaterials.com**

NexTech Materials, Ltd. is a leading provider of materials solutions for fuel cells and fuel cell related products. Founded in 1994, NexTech focuses its ceramic products and product development on areas where cost reduction, volume and weight reduction, and improved performance are critical. NexTech has core competencies in ceramic material development, materials synthesis and fabrication, coating materials, catalysis, and nanomaterials. Applications for NexTech's products include solid oxide fuel cell components, fuel processing catalysts and components, and sensors for fuel cell systems.

NexTech works with a large number of OEMs, fuel cell developers, fuel processing companies, technology development firms, universities and national laboratories. Its development philosophy has always been to assemble a team that can solve a materials-related problem while creating a clear commercialization path for new technology. NexTech's developmental products are now being tested in a number of prototype fuel cell systems.

NexTech distributes its materials through its wholly owned Fuel Cell Materials division on its companion website. Included for sale are its ceramic raw materials for solid oxide fuel cells and catalysts. Fuel Cell Materials also has an associate program that allows it to distribute new materials from other vendors and developers.

NexTech Materials, Ltd. is a privately held firm located in Worthington, Ohio, a suburb of Columbus. NexTech currently employs 20 people.

NEXTECH MATERIALS

NISSAN

www.nissan-usa.com

Nissan is expanding its fuel cell research and development program in the United States through its participation in the California Fuel Cell Partnership and, beginning in 2001, a demonstration program.

The Partnership, which also includes other automakers, energy providers, a fuel cell manufacturer, government leaders and a methanol producer, is a voluntary effort to advance a new automobile technology that could move the world toward practical and affordable environmental solutions. By demonstrating fuel cell-powered electric vehicles under real day-to-day driving conditions, the Partnership will focus on raising consumer awareness and explore the path to commercialization of fuel cell technology.

"This partnership provides us an opportunity to explore ways to develop environmentally beneficial technology," said Debra Sanchez Fair, vice president, corporate communications, Nissan North America, Inc. "Fuel cell technology holds a great deal of promise, and the partnership will help us to realize its potential."

Although development in the United States is just beginning, in Japan, Nissan has completed initial development and has begun driving tests of a fuel cell vehicle equipped with a methanol reformer. The methanol reformer produces hydrogen through the use of a catalyst to induce chemical reactions between methanol and water. The use of methanol means this kind of system is highly practical as an automotive powertrain for near-future application.

The Nissan Fuel Cell Vehicle adopts a high-efficiency neodymium magnet synchronous traction motor combined with lithium-ion batteries that enable the vehicle to achieve optimum electric power by switching between a fuel cell-powered driving mode and a battery-powered driving mode.

NUVERA FUEL CELLS

www.nuvera.com

Nuvera is a leading designer and developer of fuel processors, fuel cell stacks, and integrated fuel cell systems for stationary and transportation applications. The international firm's fuel processors and proton exchange membrane, or PEM, fuel cell stacks have been successfully tested and evaluated by major automobile and appliance manufacturers, research institutions, and industrial and energy companies.

Nuvera was formed in April 2000 through the merger of De Nora Fuel Cells S.p.A., the fuel cell division of the Italian engineering concern De Nora S.p.A., and Epyx Corporation, the fuel processing division of the American business and technology consulting firm Arthur D. Little, Inc. At the time of the merger, a minority share in Nuvera was sold to Amerada Hess Corporation, a leading east coast provider of fuel oil, natural gas, and electricity to industrial and commercial customers.

Nuvera combines the proven technology leadership of two well-established global firms. Epyx' technology enables the conversion of gasoline and other commonly available hydrocarbon fuels into hydrogen to produce electricity. Since 1992, Epyx consistently demonstrated its expertise in creating novel fuel processors in power capacities ranging from 300 watts to 200 kilowatts. These processors are capable of generating enough electricity to power everything from an automobile to a home or small commercial building.

De Nora Fuel Cells, in conjunction with De Nora Group, had delivered fuel cell stacks to customers around the world in the stationary and transportation markets since 1993. The fuel cell stacks utilize the hydrogen created by the Epyx fuel processors to generate clean, efficient energy. To date, the two companies have built and tested approximately 34 fuel processors and 255 fuel cell stacks over the last 10 years.

PORVAIR FUEL CELL TECHNOLOGIES

www.porvair.com

Porvair Fuel Cell Technologies was formed to develop new product applications based around its core competency in porous structures, ceramics and metals. Formerly, the company was the new product development wing of the Selee Corporation, the world's leader in porous ceramic filters for metal filtration. The two companies share the same site in Hendersonville, North Carolina, and both are divisions of Porvair Advanced Materials based in the U.K.

The fuel cell industry has long been interested in porous materials. Porvair's reticulated ceramic foam structures have been tested in several applications in the fuel cell system and are currently being used in a demonstration transportation fuel cell system. It was the recent acquisition of metal foam technology, however, that has really added the impetus to Porvair's fuel cell activities. Metal foam is lightweight, robust, with high heat transfer capabilities. It exhibits low pressure drop in relationship to its surface area. It can be fabricated into thin cross sectional areas from non-corrosive super alloys and metals. All of these attributes make it an attractive material for fuel cell development.

Currently Porvair's activities with fuel cell vehicles include testing programs with a number of the leading fuel cell developers in the industry. Metal foam is being used in prototype, high efficiency heat exchangers. It also can be found in the reform catalyst system as catalytic substrates. The material has and is being evaluated as flow distribution plates in fuel cells.

"Fuel cell technology is going to be a major emerging market in the next ten years. We have been given the green light by our top management to allocate considerable resources to take advantage of the opportunities that will present themselves to us," commented Jim Stike, president of Porvair Advanced Materials.

RENEWABLE FUELS ASSOCIATION

www.ethanolrfa.org

The ability to reform hydrogen from liquid fuels such as ethanol on board a vehicle represents an attractive option for fuel cell vehicle applications. Coupling renewable ethanol with the efficiency of a fuel cell will result in substantial air quality benefits. In addition, the production and use of ethanol offers significant rural economic development opportunities and national energy security benefits from the domestic production of energy.

Because ethanol is easier to store on a vehicle than hydrogen, it offers a practical alternative to direct hydrogen fueling. Ethanol is easy to distribute and is currently used in every state in the nation as an octane enhancer or oxygenate blended with gasoline. Ethanol's infrastructure to the terminal level is complete and the gasoline industry has experience handling and blending ethanol. In addition, ethanol is easier to reform than gasoline and most alternative fuels because of its relatively simple molecular structure. Finally, the industry is rapidly expanding, from 1.8 billion gallons annually produced in 22 states to more than 3.5 billion gallons expected by 2003. Production from cellulose promises to add an additional 3-4 billion gallons a year by 2010.

Nuvera has developed a multi-fuel processor that is capable of converting several fuels, including ethanol and gasoline, into hydrogen to power a fuel cell. The multi-fuel processor, when combined with a PEM fuel cell, can be packaged in a passenger car or bus to create a low-emission, high-efficiency fuel cell vehicle operating on ethanol. Ethanol provides higher efficiencies, fewer emissions, and better performance than other fuel sources, including gasoline, in the Nuvera fuel processor. The Chicago Transit Authority (CTA) has plans to use the Nuvera multi-fuel processor for an ethanol fuel cell bus program.

SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

www.aqmd.gov

The South Coast Air Quality Management District (SCAQMD) is positioned to bridge the gap between the technology challenges presented with the opportunities to incentivize implementation of low emission advanced technologies. The challenge for the SCAQMD is to identify project or technology opportunities in which its available funding can make a difference in making progressively cleaner technologies a reality in the Los Angeles Region Air Basin.

One of the key areas identified by the SCAQMD Technology Advancement program is fuel cell development and demonstration. Fuel cells are emerging as a leading alternative technology to power zero emission vehicles (ZEVs) and near-ZEVs. These ultra-clean electrochemical engines can provide excellent performance and range along with fast refueling for vehicles, and have potential to work in virtually every mobile and stationary application currently powered by internal combustion engines.

Since 1989, the SCAQMD has invested over $9.2 million in fuel cells and related technologies. The projects funded have included feasibility studies, proof-of-concept fuel cell vehicle demonstrations, advanced fuel cell and component development, reformer and infrastructure technologies, stationary fuel cell power plants, and technology transfer activities.

Future efforts are expected to focus on the following: development of fuel cell balance-of-plant technologies related to fuel storage, fuel processing, and infrastructure; scale-up of advanced fuel cell systems and integration into vehicles for demonstration; and technology improvements in fuel cell power density, systems efficiency, systems integration, and cost reduction.

The SCAQMD Technology Advancement program includes projects to develop, demonstrate, and commercialize a variety of technologies, from near-term to long-term, that are intended to provide solutions to Southern California's air quality problems.

STUART ENERGY SYSTEMS

www.stuartenergy.com

With over 50 years of experience in manufacturing hydrogen-producing equipment and as a member of the California Fuel Cell Partnership, Stuart Energy is a world leader in the development and provision of hydrogen generation and supply equipment. Recent advances in Stuart's proprietary technology has allowed the company to expand its market opportunities to include larger industrial hydrogen markets, regenerative power and transportation markets.

Stuart Fuel Appliances use only electricity and water to produce high quality hydrogen needed for vehicle applications such as the fuel cell. The Fuel Appliance (Fueler) is ideal to meet the fuel needs of hydrogen vehicles as they are introduced to market. The modular, easy to use design of the Stuart Fueler can expand to accommodate the growing number of hydrogen vehicles as they are introduced. Modules can be added as the demand for hydrogen fuel increases. In addition the Fuelers are highly portable, making re-locating to a different site relatively easy.

Stuart is currently developing a complete line of products including: the Community Fueler, a completely packaged unit ideally situated at the corner lot or at fleet sites; the Bus Fueler, designed to meet the needs of an expanding hydrogen bus fleet (currently being demonstrated at SunLine Transit in Palm Springs, California, and demonstrated at a recently completed project at Coast Mountain Transit, Vancouver, British Columbia); and finally the Personal Fuel Appliance, a prototype developed for use at the family home, providing the ultimate in distributed and convenient hydrogen (Stuart has signed an agreement with Ford Motor Company to test and evaluate a series of Personal Fuel Appliances over the next 2 years).

SYNTROLEUM

www.syntroleum.com

Syntroleum Corporation is the developer and owner of the proprietary Syntroleum Process for the catalytic conversion of natural gas into synthetic liquid fuels and specialty products. The company has licensed its process to numerous oil and gas companies and a governmental agency (non-U.S.). The Syntroleum Process is a simplification of traditional gas-to-liquids (GTL) technologies, aimed at substantially reducing both capital and plant operating costs. A unique characteristic and primary advantage of the Syntroleum Process over competing processes is its use of air, rather than pure oxygen, in the conversion process, which allows considerable reduction in plant cost, safer operating conditions, as well as smaller plant footprint.

Fuel products of the Syntroleum Process include synthetic analogs of conventional diesel, kerosene and naphtha, as well as designer fuels for specialized applications. GTL synthetic fuels are free of known fuel cell catalyst poisons (non-detectable levels of sulfur, metals or aromatics). These fuels have a very low toxicity and low water solubility. They are biodegradable. Hydrogen yield per unit volume of synthetic fuel delivered as feed to a fuel cell is roughly double that of other alternative fuels now under consideration for fuel cells. Natural gas feedstock for GTL production is abundant worldwide, and GTL synthetic fuel products can be transported through the existing world fuel distribution system.

The choice of fuel is critical to the pace of fuel cell commercialization. Synthetic fuel is capable of satisfying the demands of both present and future transportation propulsion technologies. Testing has confirmed their ideal suitability for use in both advanced compression ignition engines and fuel cells. The ability of synthetic fuels to match the needs of clean diesel engines and fuel cells means it can play a critical role in the transition to new technologies. The existence of such a transition fuel will significantly assist fuel cell commercialization.

TEXACO

www.texaco.com

Texaco, one of the world's most recognized energy providers, is at the forefront of emerging energy technology. Whether drilling to the deepest depths in the ocean off the coast of West Africa or partnering with a small advanced technology company in Troy, Michigan, Texaco is fueling the future.

Texaco Energy Systems Inc., a wholly owned subsidiary of Texaco Inc., was established in 1999 to harness the company's fuel conversion expertise to advance commercialization activities in the areas of fuel cells and hydrocarbons-to-liquids. Combining recognized industry leadership in fuel processing and feedstock conversion with emerging fuel cell technology, Texaco will be a leader in helping to commercialize this energy opportunity.

Finding a way to convert a broad range of readily available hydrocarbon fuels into hydrogen is a critical step in the effort to commercialize fuel cells. More than 50 years of experience in producing hydrogen through gasification technology and many years as a generator of electricity make Texaco uniquely qualified to respond to the needs of the fuel cell business. Texaco's world-class gasification technology is capable of converting hydrocarbon feedstocks, such as petroleum coke, natural gas, and refinery by-products, into higher value gases, including hydrogen. Worldwide, there are 68 Texaco-owned or licensed gasification plants operating or under construction, with 14 dedicated to the production of hydrogen.

The company's objective is to ensure that consumers continue to enjoy the convenience now available when using conventional transportation and power supply technology, including broad availability, cost effectiveness and safety, while capturing the efficiencies and clean energy associated with fuel cells.

Texaco has the experience and intellectual capital to help rationalize the array of fuel challenges surrounding the commercialization of fuel cells and ensure that it continues in its tradition as a global energy supplier.

W.L. GORE & ASSOCIATES

www.wlgore.com

W. L. Gore & Associates, Inc., the company that invented expanded polytetrafluoroethylene (ePTFE), is the leader in this world-renowned technology. Over the past four decades, the company has transformed its technical and process know-how into thousands of products, including a wide range of proven, high-performance electrochemical offerings.

Gore Fuel Cell Technologies delivers the highest performance and most cost effective solutions to the PEM fuel cell market. Building on over twenty years experience in electrochemistry, broad composite membrane knowledge, and the use of unique ionomers and catalysts, Gore's PRIMEA® membrane electrode power assemblies are designed for operations with hydrogen or reformate fuel streams. Gore Fuel Cell Technologies offers a continuous path to the most advanced products for stationary, residential, transportation and portable applications. To maximize product performance and durability, all PRIMEA® membrane electrode power assemblies are offered with optional components such as integral gasketing and CARBEL™ gas diffusion media.

ZETEK POWER CORPORATION

www.zetekpower.com

ZeTek Power (Zero Emission Technology Company) is the European leader in zero-emission fuel cell technology. ZeTek fuel cells can be integrated into systems to supply clean, reliable and cost efficient electric power for use in vehicles, watercraft and stationary applications. The company has administrative headquarters in London (UK) and New York (USA), R&D sites in Belgium, France, Holland and Russia and production plants in Germany and Tennessee (USA), with extensive global expansion forecast.

ZeTek's automotive division ZeVco is a core constituent of the business. Since its incorporation in the mid-1990s, ZeVco has made significant technological advances, and has demonstrated that high-efficiency (up to 65%) zero-emission vehicles, with a range comparable to conventional models, can be a reality.

Today ZeVco's "fleet" of commercial vehicles exists in modest numbers, but represents several key areas of operation. Delivery vans, public service vehicles and taxis are recognised as major contributors to city pollution. All of these applications are key target markets for ZeVco. The vehicles have no toxic or particulate emissions and are silent in operation, thus complying with emissions legislation and urban noise restrictions. The ZeVco fleet includes a Metrocab demonstration taxi and Iveco parks vehicle developed for the City of Westminster. The cab runs on the latest ZeTek system, the "Program A" - in this case adapted to transportation. The "Program A" is a result of collaboration between ZeVco and Fuel Cell Systems, a ZeTek wholly owned subsidiary specialising in systems design and integration.

All first generation vehicles will have a fixed duty cycle because of refuelling and therefore range restrictions. The company will increase its business via the ZeTek Approved Systems Integrator or ZASI programme. The programme encourages technical and commercial partners to provide the link from ZeTek to its end user customers. This process will ensure a rapid yet controlled dissemination of ZeTek's technology, and will hasten its entry into the market.

FUEL CELL VEHICLE GLOSSARY OF TERMS

ACTIVATION. *Chemical.* Treatment of a substance by heat, radiation, or other activating reagent to produce a more complete or rapid chemical or physical change. *Electrical.* The process of treating a cathode to increase its rate of reduction.

AIR. The mixture of oxygen, nitrogen and other gases which, with varying amounts of water vapor, forms the atmosphere of the earth. Also referring to any or all air for combustion, heating, cooling, ventilation and other uses as follows: *Ambient.* Air that surrounds the equipment; *Atmospheric.* Air under the prevailing atmospheric conditions; *Recirculated.* Air removed from a space and intended for reuse as supply air; and *Supply.* That air delivered to each or any space in the system or the total delivered to all spaces in the system.

ALKALINE FUEL CELL (AFC). A type of hydrogen/oxygen fuel cell in which the electrolyte is concentrated KOH (35 - 50%, a liquid) and hydroxide ions (OH-) are transported from the cathode to the anode. Temperature of operation is typically in the range of 60 - 90ºC.

ANODE. The electrode in a fuel cell where electrons are produced.

AUXILIARY POWER. Power from an independent source that functions as required to augment/support various performance criteria established for the prime power source.

BALANCE-OF-PLANT. Supporting/auxiliary components, based on site-specific requirements and integrated into a comprehensive power system package centered around the power source.

BIPOLAR PLATES. Conductive plate in a fuel cell stack that acts as an anode for one cell and a cathode for the adjacent cell. The plate may be made of metal or a conductive polymer (which may be a carbon-filled composite). The plate usually incorporates flow channels for the fluid feeds and may also contain conduits for heat transfer.

BLOWER. A fan used to force air and/or gas under pressure.

BRITISH THERMAL UNIT. The mean British Thermal Unit (BTU) is 1/180 of the heat required to raise the temperature of one pound (1 lb.) of water from 32ºF to 212ºF at a constant atmospheric pressure. It is about equal to the quantity of heat required to raise one pound (1 lb.) of water 1ºF.

BURNER. A device for the final conveyance of the gas, or a mixture of gas and air, to the combustion zone (also see Main Burner).

CATALYST. A chemical substance that increases the rate of a reaction without being consumed, after the reaction it can potentially be recovered from the reaction mixture chemically unchanged. The catalyst lowers the activation energy required, allowing the reaction to proceed more quickly or at a lower temperature.

CATALYST COATED MEMBRANE (CCM). Term used to describe a membrane (in a PEM fuel cell) whose surfaces are coated with a catalyst/carbon/binder layer. (See also Membrane Electrode Assembly [MEA].)

CATALYST LOADING. The amount of catalyst incorporated in the fuel cell per unit area. Typical units for PEMFC are mg/cm^2.

CATHODE. The electrode in a fuel cell where electrons are consumed.

COMBUSTION. The rapid oxidation of fuel gases accompanied by flame and the production of heat, or heat and light.

COMPRESSOR. A device used for increasing the pressure and density of gas.

CONDENSATE (CONDENSATION). The liquid that separates from a gas (including flue gases) due to a reduction in temperature.

CONTROLS. Devices designed to regulate the gas, air, water or electrical supplies to the controlled equipment. These may be manual, semi-automatic or automatic.

CONVECTION. Stirring or hydrodynamic transport. Generally fluid flow occurs because of natural convection (convection caused by density gradients), and forced convection, and may be characterized by stagnant regions, laminar flow and turbulent flow.

CURRENT DENSITY. A vector-point function describing the magnitude and direction of charge flow per unit area, generally expressed in amperes per square meter.

DESULFURIZER. A component for removing sulfur from a fuel mixture.

DIFFUSION. Movement of a species under the influence of a gradient of chemical potential (i.e. a concentration gradient).

DIRECT INTERNAL REFORMING. Production of a desired product (hydrogen) within a fuel cell from a hydrocarbon based fuel (methanol, gasoline, etc.) fed to the fuel cell or stack.

DIRECT METHANOL FUEL CELL (DMFC). A type of fuel cell in which the fuel is methanol (CH^3OH), in gaseous or liquid form. The methanol is oxidized directly at the anode with no reformation to hydrogen. The electrolyte is typically a PEM.

DISTILLATE. A product formed by heating a liquid in a vessel and collecting and condensing the resulting by-product(s).

EFFICIENCY. A measure (usually a ratio) of the useful energy provided by a dynamic system versus the total energy supplied to it during a specific period of operation.

ELECTRICAL EFFICIENCY. The ratio of useful electrical real power output to the total electrical power input.

ELECTRODE. An electric conductor through which an electric current enters or leaves a medium, whether it be an electrolytic solution, solid, molten mass, gas, or vacuum.

ELECTRODE ASSEMBLY. The portion of an automatic ignition system containing the electrode(s) and associated insulators, wire lead terminals, spark gap adjustment means and mounting brackets.

ELECTROLYTE. A non-metallic insulating material in which current flow in an external circuit is made possible by the movement of ions through the electrolyte.

EXHAUST HEAT. Waste heat produced by a mechanical, chemical, or electrochemical process.

EXHAUST HEAT RECOVERY. The use of by-product heat as a source of energy.

EXTERNAL REFORMING. The production of hydrogen from a hydrocarbon fuel (methanol, gasoline, etc.) prior to entry to the fuel cell or stack.

FAN. A device consisting of a rotor and housing for moving air or gas at relatively low pressure differentials.

FLUE GASES. Products of combustion plus excess air in appliance flues or heat exchangers.

FLUE LOSSES. The sensible heat and latent heat above ambient temperature of the flue gases leaving gas utilization equipment.

FUEL CELL. An electrochemical device that can continuously convert the chemical energy of a fuel and an oxidant to electrical energy. The fuel and oxidant are typically stored outside of the cell and transferred into the cell as the reactants are consumed.

GAS. Fuel gas, such as natural gas, undiluted liquefied petroleum gases (vapor phase only), liquefied petroleum gas-air mixtures, or mixtures of these gases.

GAS TURBINE. A turbine rotated by expanding gases.

GROSS POWER. The fundamental power output of an energy source prior to any conditioning and losses associated with the production of power suitable for the connected load.

HEAT EXCHANGER. A vessel in which heat is transferred from one medium to another.

HYDROCARBON. A chemical compound of hydrogen and carbon, such as methane, propane, butane, etc.

IMPURITIES. Undesirable foreign material(s) in a pure substance or mixture.

INDIRECT INTERNAL REFORMING. The reformer section is separated, but adjacent to, the fuel cell anode. This cell takes advantage of the close coupled thermal benefit where the exothermic heat of the cell reaction can be used for endothermic reforming reaction.

INTERCOOLER. A heat exchanger for cooling gas between stages of a multistage compressor with a consequent saving in power.

IR LOSS. In an electrolytic cell, the loss equal to the product of the current (I) passing through the cell and the resistance (R) of the cell. Also referred to as IR drop.

I2R LOSS. Power loss due to the current (I) flow through the resistance (R) of a conductor.

LOAD-FOLLOWING. A mode of operation where the fuel cell power plant is generating variable power depending on the AC load demand.

LOW EMISSION VEHICLE (LEV). LEV, Low Emission Vehicle, referring to those light duty passenger vehicles that meet LEV emission control standards. California's Air Resources Board and the Federal EPA set standards for tailpipe emissions and air emissions related to the volatility of fuel used in passenger cars and light trucks. California has established several categories of vehicles, based on the maximum permitted emissions of several pollutants (See chart below). California has also established a fleet-wide emission control requirement.

California LEV II Light Duty Vehicle Standards

Mileage for Compliance	Vehicle Emission Category	NMOG (g/mi)	Carbon Monoxide (g/mi)	Oxides of Nitrogen (g/mi)
120,000	TLEV	0.156	4.2	0.6
	LEV	0.090	4.2	0.07
	ULEV	0.055	2.1	0.07
	SULEV	0.010	1.0	0.02

MAIN BURNER. A device or group of devices essentially forming an integral unit for the final conveyance of gas or a mixture of gas and air to the combustion zone, and on which combustion takes place to accomplish the function for which the equipment is designed.

MANIFOLD. The conduit of an appliance that supplies gas to the individual burner.

MEANTIME BETWEEN FAILURES. The mean exposure time between consecutive failures of a component. It can be estimated by dividing exposure time by the number of failures in that period, provided that sufficient number of failures has occurred in that period.

MEAN TIME TO REPAIR. The time interval (hours) that may be expected to return a failed equipment to proper operation.

MEMBRANE. The separating layer in a fuel cell that acts as electrolyte (a cation-exchanger) as well as a barrier film separating the gases in the anode and cathode compartments of the fuel cell.

MEMBRANE ELECTRODE ASSEMBLY (MEA). Structure consisting of a proton-exchange membrane with surfaces coated with catalyst/carbon/binder layers and sandwiched by two microporous conductive layers (which function as the gas diffusion layers and current collectors).

MOLTEN CARBONATE FUEL CELL (MCFC). A type of fuel cell consisting of a molten electrolyte of $Li2CO^3/Na^2CO^3$ in which the species CO_3^{2-} is transported from the cathode to the anode. Operating temperatures are typically near 650ºC.

NAPHTHA. An artificially produced petroleum or coal tar fraction with a volatility between gasoline and kerosene.

NATURAL GAS. A naturally occurring gaseous mixture of simple hydrocarbon components (primarily methane) used as a fuel for the production of electrical power.

NERNST POTENTIAL. An electrode potential corresponding to the reversible equilibrium between hydrogen gas at a certain pressure and the corresponding level of hydrogen ion activity.

OXYGEN-TO-CARBON RATIO. The ratio of the number of oxygen atoms to the number of carbon atoms in the fuel (e.g., methanol would have a ratio of 1, ethanol would have 0.5).

PARTIAL OXIDATION. Fuel reforming reaction where the fuel is partially oxidized to carbon monoxide and hydrogen rather than fully oxidized to carbon dioxide and water. This is accomplished by injecting air with the fuel stream prior to the reformer. The advantage of partial oxidation over steam reforming of the fuel is that it is an exothermic reaction rather than an endothermic reaction and therefore generates its own heat.

PHOSPHORIC ACID FUEL CELL (PAFC). A type of fuel cell in which the electrolyte consists of concentrated phosphoric acid (H^3PO^4) and protons (H^+) are transported from the anode to the cathode. The operating temperature range is generally 160 - 220ºC .

POLARIZATION CURVE. Typically a plot of fuel cell voltage as a function of current density (V vs. A/cm^2 or similar units). The curve is obtained under standard conditions so that fuel cell performance can be compared between different cell designs, and may be obtained by either a single cell or a stack test.

POWER CONDITIONING. The subsystem that converts the dc power from the (fuel cell) stack subsystem to ac power that is compatible with system requirements.

POWER DENSITY. (kW/liter) In the context of a single cell, the power density is often measured in terms of power/unit area of active cell, e.g., kW/sq.m.; in the context of a complete cell stack, the power density could also be defined in terms of power/unit stack volume, e.g., kW/m^3.

PREFERENTIAL OXIDATION. A reaction that oxidizes one chemical rather than another. In fuel cells, the reaction is used to preferentially oxidize carbon monoxide from the reformate stream after the water-gas shift reactor and before the fuel cell. Same as selective oxidation.

PRESSURE. The force exerted against an opposing body or the thrust distributed over a surface, expressed in weight per unit of area. *Absolute.* The pressure above zero pressure, the sum of the atmospheric and gauge pressures. *Atmospheric* (Standard). The pressure of the weight of air and water vapor on the surface of the earth at sea level, namely 29.92 inches (760 mm) mercury column or 14.69 pounds per square inch (101.3 kPa). *Barometric.* The atmospheric pressure as determined by a barometer, usually expressed in inches (mm) of mercury. *Gauge.* The pressure above atmospheric pressure. *Vacuum.* Any pressure less than that exerted by the atmosphere.

PROTON EXCHANGE MEMBRANE (PEM). The separating layer in a PEM fuel cell that acts as an electrolyte (which is proton conducting) as well as a barrier film separating the hydrogen-rich feed in the cathode compartment of the cell from the oxygen-rich anode side.

PROTON EXCHANGE MEMBRANE FUEL CELL (PEMFC or PEFC). A type of fuel cell in which the exchange of protons (H+) from the anode to the cathode via a membrane is involved in the chemical reaction producing electricity. The electrolyte is a called proton exchange membrane (PEM). The fuel cells typically run at low temperatures (<100ºC) and pressures (< 5 atm).

REACTION RATE. A measure of the speed of a chemical reaction. The reaction rate depends on the rate constant, the number of reactants involved in the reaction and their concentration. For reactions that are otherwise slow, a catalyst is employed to increase the reaction rate.

REFORMER. A vessel within which fuel gas and other gaseous recycle stream(s) (if present) are reacted with water vapor and heat, usually in the presence of a catalyst, to produce hydrogen rich gas for use within the fuel cell power plant.

REFORMATE GAS. The fluid that exits the fuel reformer and acts as feed to the fuel cell stack.

REFORMING. The thermal or catalytic conversion of petroleum naphtha into more volatile products with higher BTU ratings.

REVERSIBLE FUEL CELL. A type of fuel cell in which the chemical reactants undergo reversible reactions, such that the cell may be recharged with a separate power source if desired. For example, the hydrogen/oxygen fuel cell may be recharged by providing power for water electrolysis with hydrogen storage. Also called Regenerative Fuel Cell.

SERIES CONNECTION. The connection of electrical cells in a positive to negative pattern such that individual cell voltages are additive.

SHIFT CONVERSION. The reaction of CO and water to hydrogen and carbon dioxide. This process is performed immediately after the reformer and before the preferential oxidizer and reduces CO from approximately 10% down to 0.5% to 0.1% usually through a water gas shift reaction.

SOLID OXIDE FUEL CELL (SOFC). A type of fuel cell in which the electrolyte is a solid, nonporous metal oxide, typically ZrO^2 doped with Y^2O^3, and O^{2-} is transported from the cathode to the anode. Any carbon monoxide (CO) in the reformate gas is oxidized to carbon dioxide (CO^2) at the anode. Temperatures of operation are typically 800 - 1000ºC.

STACK LIFE. The cumulative period of time that a fuel cell stack may operate before its output deteriorates below a useful minimum value.

STACK TEST. Experiment where an electrical load is applied to a stack of fuel cells to determine its ability to perform. Normally, the output seeks two pieces of information. First is a current output at a specific cell voltage point. Second is a continuous voltage vs. current curve (polarization curve).

STACKING. The process of placing individual fuel cells adjacent to one another to form a fuel cell stack. Normally, the stack is connected in a series.

STEAM REFORMING. A process for separating hydrogen from a hydrocarbon fuel, typically natural gas, in the presence of steam. This is the commonly preferred method of bulk hydrogen generation.

STEAM-TO-CARBON RATIO. The number of moles of water per mole of carbon in either the reformate or the fuel streams. This term is used when steam is injected into the reformate stream for the water-gas shift reaction or into the fuel for steam reforming.

SUBSTACK. Typically a group of stacked fuel cells that makes up the base repetitive unit number of cells per full system stack. Substacks may form an intermediate step in manufacturing and may be used to test new stack concepts prior to scale-up to full size stacks.

TEMPERATURE. A measure of heat intensity. *Absolute.* The temperature above absolute zero, or temperature plus 273ºC or 459ºF. *Ambient.* The temperature of the surrounding medium, usually used to refer to the temperature of the air in which a structure is situated or a device operates.

THERMAL EFFICIENCY. Efficiency with which a power source transforms the potential heat of its fuel into work or output, expressed as the ratio of the useful work done by the power source in a given time interval to the total heat energy contained in the fuel burned during the same time interval, both work and heat being expressed in the same units.

THERMAL MANAGEMENT. The directing of heat entering or exiting a system.

TRANSPORTATION. Term applied to the market section that includes light duty vehicles, buses, heavy duty vehicles, and off-road vehicles.

TUBULAR CELLS. Fuel cells that are formed in cylindrical fashion and allow fuel and oxidant to flow on the inner or outer surfaces of the pipe.

TURBOCHARGER. A device used for increasing the pressure and density of a fluid entering a fuel cell power plant using a compressor driven by a turbine that extracts energy from the exhaust gas.

TURBOCOMPRESSOR. Machine for compressing air or other fluid (reactant if supplied to a fuel cell system) in order to increase the reactant pressure and concentration.

TURBOEXPANDER. **Machine for expanding air or other fluid (reactant if supplied to a fuel cell system) in order to decrease the reactant pressure and concentration. The unit is normally used in conjunction with a compressor to recover unused energy from hot, pressurized gasses, thereby reducing the net amount of energy required to power the compressor.**

VESSEL, PRESSURE. **Containers for the containment of pressure either internal or external. This pressure may be obtained from an external source, or by the application of heat from a direct or indirect source, or by any combination thereof. Exceptions: vessels having an internal or external operating pressure not exceeding 15 psi (103.4 kPa) with no limitation on size; vessels having an inside diameter, width, height or cross section diagonal not exceeding six (6) inches (152 mm) with no limitation on length of vessel or pressure.**

ZERO EMISSION VEHICLE (ZEV).
Zero Emission Vehicle, a vehicle that produces no air emissions from its fueling or operation. California regulations require in 2003, 10% of the vehicles sold in California by major auto makers be ZEV or ZEV equivalent. California has established a comprehensive program for determining this equivalency. See also LEV.

NOTES

"Now dozens of manufacturers and many large companies are considering fuel-cell development in an industry that has one of the fastest-growing trade associations in the country - the U.S. Fuel Cell Council in Washington, D.C."

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US Fuel Cell Council

1625 K Street, N.W., Suite 725
Washington, D.C. 20006
(202) 293-5500
Fax (202) 785-4313
www.usfcc.com

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