Draft Funding Opportunity Announcement
Research and Development of Polymer Electrolyte Membrane (PEM) Fuel Cells for the Hydrogen Economy

The Department of Energy (DOE) is planning to issue a solicitation in August 2005 for polymer electrolyte membrane (PEM) fuel cell research and development (demonstrations and manufacturing will not be included in this solicitation). A DOE PEM Fuel Cell Pre-Solicitation Workshop will be held Thursday, May 26, 2005 from 1:00 - 5:00 PM in conjunction with the 2005 DOE Hydrogen Program Review at the Crystal Gateway Marriott in Crystal City (Arlington), Virginia. During the workshop, potential topics of fuel cell research and development will be presented and discussed. **Written comments** on the potential topics included below and additional topic areas are being requested **on or before May 15, 2005**. Written comments **are limited to 2-pages** using 12 point font and should be submitted to fuelcells@go.doe.gov.

The DOE funding anticipated for this solicitation is approximately $70 million over 3 years. Applicant cost sharing of 20% for research and 30-40% for development will be required. It is anticipated that there will be 1-3 awards per topic.

The research and development will be focused on advancing PEM fuel cell technology towards the 2010 technical performance and cost targets as detailed in the DOE Hydrogen, Fuel Cells, and Infrastructure Technologies Program Multi-Year RD&D Plan, http://www.eere.energy.gov/hydrogenandfuelcells/mypp/. Proposed research in the following topic areas is proposed.

Topic 1	**Improved Fuel Cell Membranes**
Topic 1 A	Development of Low-Humidity Proton Conducting Materials
Topic 1 B	Improving Durability of Membranes
Topic 1 C	Development of High-Performance Membranes
Topic 2	**Water Transport Within the Stack**
Topic 2 A	Exploratory Studies
Topic 2 B	Engineering Studies
Topic 3	**Advanced Cathode Catalysts and Supports**
Topic 3 A	Catalyst Durability
Topic 3B	Development of high-temperature catalyst materials
Topic 3C	Development of low-cost catalyst materials
Topic 4	**Cell Hardware**
Topic 4 A	Bipolar Plates
Topic 4 A 1	Carbon Bipolar Plates
Topic 4 A 2	Metal Bipolar Plates
Topic 4 B	Seals
Topic 5	**Freeze-Capable Stack**
Topic 5 A	Exploratory Studies

Topic 1 Improved Fuel Cell Membranes

Membranes are a critical component of the fuel cell stack and must be durable and tolerate a wide range of operating conditions including low humidity and high temperature. The low operating temperature and the membrane's humidity requirements add complexity to the fuel cell system that impacts the system cost and durability. Improved membranes need to be simpler, perform better and be less expensive than the current generation of PEM.

Applications are sought that address these critical limitations and the need to operate the fuel cell system without external humidification and at higher temperature. Applicants may address one or more of the research areas detailed below. Go/No-Go decision points for research in these areas are necessary and should be used when an application includes materials development work that must succeed before proceeding to membrane electrode assembly (MEA) testing.

Teaming of a polymer science group, an MEA manufacturer, and a fuel cell manufacturer is encouraged.

Topic 1 A Development of low-humidity proton conducting materials

Proposals should synthesize membrane materials that conduct protons at low relative humidity (25-50% RH), withstand temperatures up to 120°C, and be electrically insulating. While the membrane does not necessarily need to be polymeric in nature, the material must possess properties that enable it to be coated with a catalyst suitable for fuel cell operation. The proposed membrane material must meet the conductivity requirements over a range of operating conditions from -20°C to 120°C (see Table 1), the start-up time from cold temperatures and the efficiency targets. Additionally the membrane must demonstrate the ability to meet the cost and durability targets in the aggressive environment of the fuel cell, and have good mechanical and chemical stability under highly oxidizing conditions.

Table 1. Technical Targets: Membranes			
Characteristic	Units	2004 Status	2010 Target
Membrane Conductivity at Operating Temperature[b] Room temperature -20°C	 S/cm S/cm S/cm	 0.10 0.07 0.01	 0.10 0.07 0.01
Operating Temperature	°C	≤80	≤120
Inlet water vapor partial pressure	kPa	50	1.5
Oxygen cross-over[a]	mA/cm^2	5	2
Hydrogen cross-over[a]	mA/cm^2	5	2
Arial Specific Resistance	$Ohm\ cm^2$	0.03	0.02
Cost	$\$/m^2$	65[b]	40
Durability with cycling At operating temp of ≤80°C At operating temp of >80°C	 hours hours	 2000[c] not available[e]	 5000[d] 2000
Survivability	°C	-20	-40
Thermal cyclability in presence of condensed water		Yes	Yes

[a] Tested in MEA at 1 atm O_2 or H_2 at nominal stack operating temperature.
[b] Based on 2004 TIAX Study that will be periodically updated.
[c] Durability is being evaluated. Steady-state durability is 9,000 hours.
[d] Based on appropriate test protocol (to be issued in 2007).
[e] High-temperature membranes are still in a development stage and durability data are not available.

Topic 1 B Improving durability of membranes

In this task, applicants will develop membranes with increased durability in fuel cell conditions. Applications are being solicited to:

- Conduct research to elucidate failure mechanisms and develop technologies to meet the design lifetime requirement (40,000 hours operation for stationary applications, >5,000 hours with cycling for transportation applications, with <10% degradation in performance for both applications)

- Research, develop, and demonstrate membrane systems that address and mitigate the failure mechanisms for transportation and/or stationary applications with a design lifetime target of 5,000 and 40,000 hours, respectively

The development of accelerated/short-term test procedures that could be used to determine the long-term durability of the membranes would be extremely desirable in shortening the time required to test candidate systems. Applicants should discuss their understanding of the materials and operating factors (and their relative importance) that affect membrane durability and discuss how accelerated tests relate to real-time testing. Extended testing (>2000 testing hours) should be conducted to characterize the life expectancy and performance degradation.

Topic 1 C Development of high-performance membranes
Cost studies have indicated that increased membrane performance can lead to substantial cost reductions. In this topic, membranes that decrease the ionic resistance as well as the fuel and oxygen crossover by a factor of two compared to the current state-of-the-art (Nafion 112™) membranes are solicited. The material must be processed into catalyst-coated membranes suitable for fuel cell operation, and the membrane must be compatible with the electrocatalysts. The membrane must meet the conductivity requirements over a range of operating conditions from -20 ^{o}C to 100 ^{o}C, and withstand the stresses and forces expected in an automotive fuel cell stack operation under real-world driving cycles. Applicants should provide sufficient rationale that their concept could lead to projected area-specific resistance in a fuel cell of ≤0.02 ohm-cm^2 under operating conditions. Targets for tensile strength and yield strength are ≥6 kpsia and ≥4 kpsia, respectively. Applicants should also show that the membrane can be expected to meet the technical targets in Table 1.

Deliverables (for 1A, 1B, and 1C)

- Results from testing MEA (50 cm^2) and full-area (250 cm^2) short stack (≥10 cells) made with improved membrane material demonstrating low-humidity operation, improved durability, including testing according to the DOE Durability protocol (will be finalized referenced when solicitation is issued).
- Short stack used in establishing performance results delivered to DOE for independent testing.

Topic 2 Water Transport within the Stack

Effective management of the water produced in the fuel cell can alleviate problems with flooding of the catalysts and drying out of the membrane. Ineffective water management leads to liquid-phase water blockage and mass transport limited performance and/or decreased protonic conductivity in the membrane and catalyst layers due to dehumidification of the ionomer. The designs of the gas diffusion layers (GDLs), gas flow fields in bipolar plates, catalyst layers and membranes affect water management. DOE is soliciting proposals for research to optimize water management within the fuel cell stack to decrease the complexity and cost of a fuel cell system. Proposals should address:

- Prevention of flooding of the cathode and/or GDL during operation at peak power conditions.
- Prevention of dehumidification of the ionomer in the membrane, anode and cathode catalyst layers.

Different fuel cell system configurations may require different levels of water removal and/or humidification. Proposals are sought in the areas of exploratory studies and engineering solutions. Proposals covering both subtopics are allowed if appropriate teaming is evident and the deliverable is a full-area (250 cm^2) short stack (≥10 cells) meeting the requirements of Topic 2B.

Topic 2 A Exploratory Studies

The goal of this subtopic is to develop an understanding (not design-specific) of the water and gas transport in the fuel cell stack during operation (i.e. GDL, catalyst layers and flow channels) and how the materials properties of the subsystems affect water transport. Examples of exploratory studies include:

- Experimentation and/or modeling of the state of water and degree of membrane, catalyst layer, and GDL saturation as a function of operating conditions and material properties, e.g. porosity and hydrophobicity
- Materials and component development to enhance water transport and decrease flooding and ionomer dehumidification.

Topic 2 B Engineering Studies

The goal of this topic is the demonstration of effective water management in a full-area (250 cm^2) short stack (≥10 cells). Examples of engineering studies include:

- Development and demonstration of a cell package which allows for improved fuel cell performance with self humidification
- Development and demonstration of a cell package which allows for improved fuel cell performance under high-power conditions where flooding is normally observed

Deliverables (for 2A and 2B)

- The deliverable for Subtopic 2A is a final report.
- The deliverable for Subtopic 2B is a multi-cell stack (≥10 cells) incorporating full scale cells (250 cm^2) that meets the DOE performance targets, delivered to a DOE laboratory for independent testing.

Topic 3 Advanced Cathode Catalysts and Supports

Electrocatalysts are a major contributor to the fuel cell cost and performance. To reduce costs and improve performance, advances are needed in cathode catalyst activity and durability. The targets and the status for electrocatalysts for use in a direct hydrogen fuel cell for transportation applications are included in Table 2. This topic seeks proposals to address the shortcomings of current cathode catalyst technology by addressing the gaps between the current status and the 2010 targets. Applicants may address one or more of the research areas detailed below. Go/No-Go decision points for research in these areas are necessary and should be used when an application includes materials development work that must succeed before proceeding to membrane electrode assembly (MEA) and stack testing.

Table 2: Technical Targets: Electrocatalysts

Characteristic	**Units**	**Cell Status**	**Stack Status**	**2010 Target**
Platunim group metal Total Content	g/kW rated	0.6	1.3	0.30
Platinum group metal Total Loading [a]	mg PGM/cm^2 electrode area	0.45	0.80	0.30
Cost	\$/kW [b]	9	20 [c]	8
Durability with cycling Operating temp ≤80°C Operating temp >80°C	 Hours Hours	>2000 (not avail.) [f]	~2000[d] (not avail.) [f]	5000[e] 2000
Mass Activity [g]	A/mgPt @900mV$_{iR-free}$	0.28	0.11	0.44
Specific Activity [g]	μA/cm^2 @ 900mV$_{iR-free}$	550	180	720
Non-Pt Catalyst Activity per volume of supported catalyst	A/cm^3@800mV$_{iR-free}$	8	not avail.	>130

[a] Derived from achieving performance at rated power targets specified in Table 7.3. Loadings may have to be lower.

[b] Based on platinum cost of $450/troy ounce = $15/g, and loading < 0.2 g/kWe

[c] Based on 2004 TIAX study and will be periodically updated.

[d] Durability is being evaluated. Steady state durability is 9,000 hours.

[e] Based on appropriate test protocol (to be issued in 2007).

[f] High-temperature membranes are still in a development stage and durability data is not available.

[g] Test at 80°C/120°C H_2/O_2; fully humidified with total outlet pressure of 150 KPa; anode stoichiometry 2; cathode stoichiometry 9.5.

Topic 3 A Catalyst durability

Durability of the electrocatalyst is a major technical barrier for stationary and transportation applications of PEM fuel cells where the expected stack-operating design lifetime is up to 40,000 hours. Platinum (Pt) sintering and dissolution as well as carbon corrosion pose significant concerns at the high electrode potentials. These issues are especially important for higher temperature operation (>100°C), which is desired for both stationary and automotive applications. In the literature, a half-life of less than 200 h has been estimated for Pt catalysts at 0.9V and 120°C.

Applications are being sought to:

- Conduct research to elucidate failure mechanisms and develop technologies to meet the design lifetime requirement (design 40,000 hours operation for stationary, 5,000 hr under cyclic operation for transportation, with <10% degradation in performance) with total Pt loadings less than 0.4 mg/cm^2
- Research and develop cathode catalyst systems that address and mitigate the failure mechanisms for transportation and/or stationary applications with a design lifetime target of 5,000 or 40,000 hours, respectively

The development of accelerated/short-term test procedures that could be used to determine the long-term durability of catalysts would be of interest to shorten the time required to test candidate systems. Applicants will discuss their understanding of the materials and operating conditions that they believe to be the key factors (and their relative importance) that need to be addressed during the cathode catalyst development and the cell/stack testing activities of the program. Extended testing (>2000 testing hours) should be conducted to characterize life expectancy and performance degradation under realistic conditions.

Topic 3 B Development of high-temperature catalyst materials

Development of alternative stable high-temperature cathode catalyst materials is desired with performance approaching or exceeding that of platinum. High temperature PEM systems are expected to ease or eliminate the need for membrane water management and CO management, and are expected to improve thermal management. Higher temperature operation will also aid in achieving success in combined heating and power applications for stationary fuel cells. The increased temperature will increase catalyst activity, i.e. increase the rate of reaction, allowing for lower catalyst loadings. The resulting systems would have substantially reduced costs. Current catalysts are not expected to be stable in a fuel cell at these elevated temperatures. Proposals to develop high-temperature cathode catalysts should indicate that the catalysts and catalyst supports have the potential to achieve the activity targets and can maintain stable operation at temperatures up to 120°C. Applications should address achieving requirements for both transportation and stationary applications: operating pressure from near ambient to 2.5 atm., a design lifetime of 40,000 hours with appropriate cycling, and a cost consistent with the targets in Table 2.

Topic 3 C Development of low-cost catalyst materials

Precious metal catalysts are currently used on the PEM anode and cathode for the electrochemical reactions. These catalysts significantly contribute to the overall cost of the fuel cell stack as well as the overall fuel cell system. There is a concern about the availability of precious metals to support the wide spread introduction of PEM fuel cell systems in the future.

DOE is interested in the development and use of low cost, low or non-precious metal cathode catalysts that meet the activity and cost targets. The applicant's approach to the development of a low or non-precious metal cathode catalyst must be clearly identified and the technical and economic viability of the proposed catalyst system must be justified. The new catalyst system should demonstrate the potential to perform at least as well as the conventional precious metal catalysts currently in use in MEAs. The cost of the catalyst must be at least 50% less than the cost for conventional catalyst on a $/kW basis. Catalyst durability of >2000 hours operation with less than 10% power degradation is desired. At the end of the project the applicant will be expected to demonstrate their low cost cathode catalyst on MEAs in a short stack (≥ 10 cells) with full plate size (250 cm^2) and deliver the stack to DOE for independent testing.

Deliverables (for 3A, 3B, and 3C)

- Results from testing the cathode catalysts in an MEA of 50 cm^2 or greater and short stack (≥10 cells) with cell active area of 250 cm^2, including the Durability Protocol.
- Short stack tested above delivered to DOE for independent testing

Topic 4 Cell Hardware

This topic requests proposals to address cell hardware issues including cost and durability of bipolar plates and seals. The Applicant must arrange for independent verification of the performance of the plates and/or seals by a fuel cell developer in addition to any proposed in-house testing.

Topic 4 A Bipolar Plates

Bipolar plates represent a significant fraction of stack cost and weight. DOE performance targets for the plates are shown in Table 3.

Table 3: Technical Targets: Bipolar Plates

Characteristic	Units	Status 2004	2010
Cost	\$/kW	10	6
Weight	kg/kW	0.36	<0.4
H_2 Permeation Flux	$cm^3\ sec^{-1}\ cm^{-2}$ @ 80°C, 3 atm (equivalent to <0.1 mA/cm^2)	$<2 \times 10^{-6}$	$<2 \times 10^{-6}$
Corrosion	$\mu A/cm^2$	<1 [a]	<1 [b]
Electrical Conductivity	S/cm	>600	>100
Resistivity[c]	Ohm cm^2	<0.02	0.01
Flexural Strength	MPa	>34	>4(crush)
Flexibility	% deflection at mid-span	1.5 to 3.5	3 to 5

Based on coated metal plates.

[b] May have to be as low as 1 nA/cm^2 if all corrosion product ions remain in ionomer.

[c] Includes contact resistance.

The plates must demonstrate in-stack performance that is at least 95 percent of the performance of an equivalent stack using machined graphite plates. The plates are expected to maintain performance over 5000 hours with less than 2 percent degradation in performance. After developer testing, the stack will be delivered to a DOE laboratory for independent testing.

It is encouraged that the team addressing this topic include a stack developer and a member with extensive high-volume, commercial manufacturing experience in the composites/plastics or metal coating field.

Topic 4 A 1 Carbon Bipolar Plates

Carbon-based bipolar plates are the current standard for PEM fuel cells. DOE seeks development and demonstration of a process for fabricating full-size active area carbon-based bipolar plates that can meet all of the DOE plate targets including the cost target of $6/kW with a reject rate of <5%. The process must be scaleable to high-volume manufacturing, although that should not be part of the proposal.

Topic 4 A 2 Metal Bipolar Plates

When compared to carbon bipolar plates, metal bipolar plates tend to have lower cost, improved performance by higher conductivity, and enhanced stack packaging (i.e., lower weight and thickness result in higher kW/kg and kW/L). Challenges associated with metal bipolar plates are primarily associated with corrosion. Plate corrosion may result in higher resistance and contamination of the electrolyte with corrosion products. In fact, metal plate corrosion products can have severe effects on the electrolyte, even in very small concentrations.

Coated or surface modified plates require high-conductivity, dense, and contiguous protective layers (no pinholes) to prevent catastrophic corrosion of the base metal and/or contamination of the electrolyte with corrosion products. The protective coating must protect all vulnerable areas including plate edges and the inside diameter of manifolds and other through-plate holes.

DOE seeks development of materials and processes for fabricating full-size active area metal bipolar plates that can meet all of the DOE plate targets including the cost target of $6/kW with a reject rate of <5%. The processes must be scaleable to high-volume manufacturing. The materials must address corrosion issues.

Topic 4 B Seals

New seal materials are sought which possess the appropriate chemical and structural integrity, electronic and ionic conductivity, gas impermeability, cost, specific power and power density. Any potential seal degradation products must be shown to have minimal effect on the membrane and other cell components.

Proposals are sought which address PEM fuel cell seal materials and structures. Applicants must demonstrate knowledge of the current status of seals. Proposals should include candidate materials and the rationale for their consideration. It is anticipated that out-of-cell testing property determination will precede *in-situ* testing. Engineering design solutions specific to one developer's plate, cell, and stack configuration will not be funded.

Deliverables (for 4A1, 4A2 and 4B)

- The deliverable for Topics 4A1 and 4A2 is a multi-cell stack (≥10 cells) incorporating full scale plates (approximately 250 cm^2) that meets the above performance and cost targets.
- The deliverable for Topic 4B is a multi-cell test (at least 50 cm^2 and at least two cells) operating for at least 2,000 hours under realistic operating conditions including some load cycling. The planned test protocol should be included in the proposal. Data to be reported include cell performance stability data and post-test chemical analysis of the seal and the MEA to quantify the stability of the seal material.

Topic 5 Freeze-capable stack

Transportation and stationary fuel cells must be able to operate in environments where ambient temperatures will fall below 0°C. To be competitive with internal combustion engines (ICE), a fuel cell vehicle (FCV) must be able to start from -20°C and drive away at 50% power within 30 seconds. Furthermore, the fuel consumption to start the vehicle should not exceed approximately 5MJ of additional energy for startup from -20°C.
For further information on this issue that was discussed at a recent DOE workshop see: http://www.eere.energy.gov/hydrogenandfuelcells/fc_freeze_workshop.html

The goals of this topic are to identify and quantify the effects of freezing temperatures on fuel cell components and operation and to identify and demonstrate remedies. The remedies must be consistent with stack cost, performance, and durability targets.

Specifically, proposals are sought in the areas of exploratory studies and engineering solutions. Proposals covering both subtopics are allowed if appropriate teaming is evident and the deliverable is a full-area (250 cm^2) short stack (≥10 cells) meeting the requirements of topic 5 B.

Topic 5 A Exploratory Studies

The goal of this subtopic is to develop a better understanding of the effects of freeze/thaw cycles on PEM fuel cell components, cells, and stacks with the aim of using the information to guide mitigation strategies. Applicants should describe how proposed studies will lead to a better understanding of the freeze/thaw cycle and ultimately lead to mitigation measures.

Examples of exploratory studies include:

- Understanding the state of water and degree of membrane, catalyst layer, and GDL saturation as a function of temperature and proton conductivity in polyfluorosulfonic acid (PFSA) and other membranes at freezing temperatures down to -40˚C.
- Water movement under temperature gradients and multiphase transport in porous media (MEA) under very low temperature conditions.
- Delineation of failure modes during freezing, including morphological changes and localized stresses in fuel cell components associated with phase transition.
- Kinetics of phase change.
- Tailoring materials and components to enhance freeze tolerance. Increased GDL/catalyst ductility. Influence of GDL wet-proofing.

Topic 5 B Engineering Solutions

The goal of this topic is to develop and evaluate engineering solutions which mitigate freeze/thaw damage and improve subfreezing operation. Engineering design solutions specific to one developer's plate, cell, and stack configuration will not be funded.

Examples of engineering issues include:

- Stack shutdown and stack startup procedures under freezing conditions to mitigate freeze/thaw damage and to minimize start-up energy.
- Stack design and operation to improve subfreezing operation and robustness.

Deliverables (for 5A and 5B)

- The deliverable for Subtopic 5 A is a final report.
- The deliverable for Subtopic 5 B is a multi-cell stack (≥10 cells) incorporating full scale cells (250 cm^2) that meets the DOE cold-temperature targets. After cold testing at the developer site, the stack will be delivered to a DOE laboratory for independent testing. The stack must, without suffering performance degradation:
    - Survive repeated soaking at -40ºC (at least 8 hours).
    - Start unassisted in 30 seconds from -20ºC and produce 50% rated power.

Topic 6 Balance of Plant

Development of low-cost, high-performance components that are qualified for automotive duty is important in achieving overall system cost and performance goals. Applicants must demonstrate through hardware testing that they could meet the DOE technical and cost targets when the hardware is integrated into a complete power system. Teaming with a fuel cell stack or system developer is encouraged so that the resultant product is applicable. The component hardware developed under this solicitation will be delivered to a DOE laboratory for independent testing.

This solicitation seeks innovative research and development of components for fuel cell systems that address the following priorities:

Topic 6 A Compressor/Expander Technologies

The goal of this topic is to develop, characterize, test, and deliver compact, efficient and low-cost air management system(s) for pressurized PEM fuel cell operation in an 80-kW_e system. Candidate air systems should incorporate an integrated compressor/expander/ motor packaged for automotive use, and be capable of maintaining a prescribed pressure ratio on a 10:1 flow turndown. New and innovative concepts are especially encouraged as well as improvements to existing technology.

The DOE technical targets for pressurized systems are presented in Table 4. The emphasis of this topic is to meet the pressure ratio guideline, help produce a fuel cell system efficiency of 50% at full power and maximize the efficiency (i.e. close to 60%) at the 25% load point. The range of the peak load pressure ratio will be approximately 2.5 atm. The machines must be built with motors capable of delivering the specified air flow if the machine does not have an expander, refer to Table 2. The system must be capable of responding to repeated load cycling.

Table 4: Technical Targets: Compressor/Expanders			
Characteristic	**Units**	**2004 Status**	**2010 Target**
Input Power [a] at Full Load, 40°C Ambient Air (with expander/without expander)	kW_e	6.3/13.7 [b]	5.4/12.8
Overall Motor/Motor Controller Conversion Efficiency, DC Input	%	85	85
Input Power at Full Load, 20°C Ambient Air (with Expander / without Expander)	kW_e	5.2/12.4 [b]	4.4/11.6
Compressor/Expander Efficiency at Full Flow (C/E Only)[c]	%	75/80 [d]	80/80
Compressor/Expander Efficiency at 20-25% of Full Flow (C/E Only) : Compressor at 1.3 PR/Expander at 1.2 PR	%	45/30 [d]	60/50
System Volume [e]	Liters	22 [b]	15
System Weight [e]	Kg	22 [b]	15
System Cost [f]	$	1500	400
Turndown Ratio		10:1	10:1
Noise at Max Flow(excluding air flow noise at air inlet and exhaust)	dB(A) at 1 m	65	65
Transient Time for 10-90% of Maximum Airflow	Sec	1	1

[a] Input power to the shaft to power a compressor/expander, or compressor only system, including a motor/motor controller with an overall efficiency of 85%. 80-kW_e compressor/expander unit for hydrogen/air flow of 90 g/sec (dry) maximum flow for compressor, compressor outlet pressure is specified to be 2.5 atm. Expander (if used) inlet flow conditions are assumed to be 93 g/sec (at full flow), 80°C, and 2.2 atm.
[b] Projected.
[c] The pressure ratio is allowed to float as a function of load. Inlet temperature and pressure used for efficiency calculations are 20-40ºC and 1 atm.
[d] Measured blade efficiency.
[e] Weight and volume include the motor and motor controller.
[f] Cost targets based on a manufacturing volume of 100,000 units per year, includes cost of motor and motor controller

Topic 6 B. Standardized Scalable Motor Drives for PEM FC Accessories

Accessory components that have been designed specifically for use in fuel cell systems are generally not available; consequently, developers use commercially available components that may compromise the performance of the system. A source for components that are available in a range of sizes and capacities covering the range of operation of fuel cell propulsion systems in vehicles would be important in developing prototype fuel cell systems. One such set of components is drives (controller/motor assemblies) for auxiliary components such as pumps, fans, blowers, and compressors. Traction motors are not considered to be auxiliary motors.

This subtopic emphasizes the development of auxiliary drives, that is, motors with integrated controllers. The design should be scalable to cover the anticipated ranges of continuously rated power, speed, dc supply voltage, mounting, and aspect ratio (diameter/ length) requirements of auxiliary equipment. All drives will be closed frame types, with any heat sinks mounted on the outside. Energy conversion efficiencies should be maximized, and weight should be minimized.

The components of the various sizes of drives are to be commercially available or easily developed by vendors. The similarities from one size to the other should be used as an advantage, where it is practical, for lowering costs of the entire family of drives. Various mounting arrangements should be accommodated to permit flexibility of use for prototyping.

The drives will be the variable speed type, handling requests for loads that vary with speed according to the pump, fan, blower, or compressor on the motor shaft. These types of loads all require nearly zero horsepower and torque at low speed, to rated power at full speed. This will give system designers the maximum opportunity to run the auxiliaries in an efficient manner. Input current ripple at full load should not exceed 20 percent.

Controller input voltage will be 12 Vdc, 48 Vdc, or stack voltage (150 to 300 Vdc). Drives rated at more than 1/3 hp (at the motor shaft) should be designed for 48 Vdc or connection to the stack voltage, to limit the full load controller input current to about 30 amperes. Drives rated at more than 1 hp should be designed for connection to the stack voltage.

All drives will use the same communication interface for their control. The interface type will be selected from existing protocols used in the automotive industry, after studying the merits of the various interfaces. The controller, mounted on or within the motor frame, will include a microcontroller interfaced to power semiconductor devices for running the motor.

All drives should be available with length/diameter ratios of 1.5, 2.0, and 2.5 (integrated controllers included). All drives will be available with C - Face, D - Flange, or Foot mounting provision. Adaptor kits can be provided for mounting and shafting changes by the customer for single unit or other small orders.

Table 4: Auxiliary Drive Speeds

Full HP	Full Speed
¼	1000
¼	2000
¼	3000
1/3	1000
1/3	2000
1/3	3000
1/2	1000
½	2000
½	3000
¾	1000
¾	2000
¾	3000
1	1500
1	3000
3	3500
5	4000
7.5	5000
10	6000

Deliverables (for 6A and 6B)
The deliverables from this topic will be a report and components delivered to a DOE national laboratory for evaluation.

Topic 7 Effects of Impurities on Fuel Cell Performance and Durability

Impurities in the hydrogen fuel that are introduced into the fuel cell anode can have a deleterious effect on the performance and durability of a fuel cell. Impurities can be diluents that reduce fuel cell performance by displacing hydrogen in the fuel stream or they can be contaminants that poison a fuel cell and cause permanent or reversible loss of performance. Species that are known to be or are suspected of being contaminants are carbon monoxide (CO), ammonia (NH_3), hydrogen sulfide (H_2S), mercaptans, halogenated compounds, hydrocarbons, formaldehyde, formic acid, and trace metals. In addition to impurities in hydrogen, air introduced into the fuel cell cathode can be expected to contain species that are harmful to fuel cells, such as sulfur dioxide (SO_2), nitrogen oxides (NO_x), and chlorides. Other compounds may become of interest depending on the source and production method for the hydrogen as well as the methods for hydrogen delivery and storage on board a vehicle.

This topic requests proposals to address the effects of impurities in the fuel and air streams on fuel cell performance and durability. The applicant should specify the impurities to be addressed in the study. It is expected that the testing will be done at a subscale or single cell level so as to screen a number of compounds of interest in a reasonable amount of time. Among the parameters that should be investigated are pressure (~100 to 400 kPa_{abs}), temperature (~4 to 65°C), catalyst loading (~0.01 to 1.0 mg Pt/cm^2), current density, and electrochemical area. The effects of impurity levels on fuel cell performance should be determined and a predictive model generated that can be used to predict the cumulative effects on an operating stack. A number of documents containing relevant background information have been generated by the US Fuel Cell Council. These reports are available at http://www.usfcc.org.

Applicants should briefly describe their proposed test plan and how it will be used to develop a predictive model elucidating cumulative effects on an operating stack. The proposed test plan should identify each contaminate that will be examined and why it is considered important.

Deliverables (for 7)

Deliverables for topic 7 include a report describing the results of contaminate impacts studies and a computer model which predicts the impacts of each contaminate studied.