RECENT DEVELOPMENT OF AUTOMOTIVE FUEL PROCESSOR TECHNOLOGIES

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Introduction

The goal of the Fuel Cells for Transportation Program at the Department of Energy (DOE) is to develop materials, components, and enabling technologies for highly efficient, low or zero-emission, cost-competitive automotive fuel cell power systems. For light-duty vehicle applications, most of the R&D efforts are concentrated on polymer electrolyte membrane (PEM) fuel cells, which operate at low temperature (80 - 90°C) and have minimal start-up and transient response times compared to other types of fuel cells. PEM fuel cells operate on direct hydrogen provided from an on-board hydrogen storage vessel or on hydrogen-rich fuel produced by an on-board fuel processor using hydrocarbon fuels. DOE is pursuing a dual fuel-pathway strategy. For near-term implementation of fuel cell vehicles, on-board fuel-flexible fuel processing is the focus of R&D efforts, taking advantage of the existing infrastructure of hydrocarbon fuels. Fuels from diverse energy sources (methanol, ethanol, natural gas, and gasoline) can be reformed in a fuel-flexible fuel processor to produce hydrogen on-board. In the long term, fuel cell vehicles will operate on hydrogen supplied by an off-board hydrogen infrastructure and which is stored on board the vehicle.

On-Board Fuel Processing Challenges

A number of critical barriers exist which prevent the commercial introduction of fuel cell vehicles into the marketplace today. The technical barriers include: cost, reliability and durability of components and systems; thermal, air and water management of systems; and a suitable hydrogen fuel infrastructure. For fuel cell vehicles with on-board fuel processors, additional issues arise which include reactor size and weight as well as fuel processor start-up and transient response time. Current fuel processors are too heavy and bulky which not only makes packaging into a passenger vehicle difficult if not impossible but significantly impacts start-up and transient operation. Current start-up times for fuel processors vary between several minutes and half an hour. A start-up time of less than 30 seconds will be needed eventually. Another issue for on-board fuel-flexible fuel processors is contamination of fuel processor catalysts by sulfur in the fuel. Sulfur levels will be lowered in the future. In 2004, EPA Tier 2 gasoline (30 ppm sulfur, 80 ppm maximum) will be introduced to reduce light-duty vehicle emissions. Even with the lower sulfur levels, some fuel processor catalysts will be irreversibly poisoned by sulfur compounds. Sulfur-tolerant fuel processor components will need to be developed for operation on the Tier 2 gasoline. Design considerations will include sulfur level in the fuel and fuel processor design, i.e., location of the desulfurizer in the chain of reactors, which make up the fuel processor.

New DOE Projects Address Fuel Processor Start-Up Issue:

To address the issues described above, DOE recently began new R&D efforts emphasizing rapid-start fuel processing technologies. These new approaches include: development of a low thermal-mass fuel processor with a novel balance-of-plant design; development of a plate reactor fuel processor to minimize reactor size and provide optimum temperature control; and optimization of microchannel reactors with microcombustor and microvaporizer components.

To achieve high efficiency and quick-start, Nuvera Fuel Cells Inc. will combine their existing low thermal-mass catalytic fuel processor with an advanced, integrated balance-of-plant. Nuvera will optimize their Substrate based Transportation application Autothermal Reformer (STAR, see **Figure 1**) which is expected to generate 161 kW of H_2 output at 80% efficiency and which will incorporate a highly efficient liquid desulfurizer. Nuvera will also redesign the fuel cell system, integrating and eliminating fuel cell and fuel processor balance-of-plant components; the combination of these R&D efforts is expected to produce <10 s start-up time and >750 W/L power density.

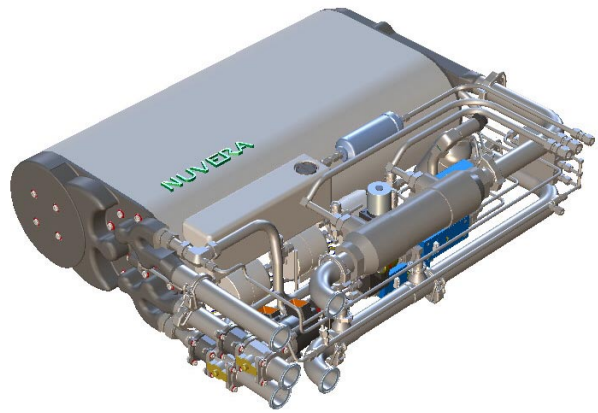

Figure 1. Nuvera's Substrate-Based Transportation Application Autothermal Reformer (STAR) Fuel Processor

Catalytica Energy Systems, Inc. will develop an innovative fuel processor system that optimizes plate-based methane steam reforming technology. In the plate-based reactor, catalytic oxidation and catalytic steam reforming are integrated within the reactor and carried out on either side of a plate. After scale-up, the fuel processor will provide several advantages including high efficiency, efficient heat transfer through the plate from the oxidation side to the reforming side, a power density of 6 kW/L, and a specific power of 2 kW/g. Since the heat exchange occurs across a single plate, the catalyst temperature can be

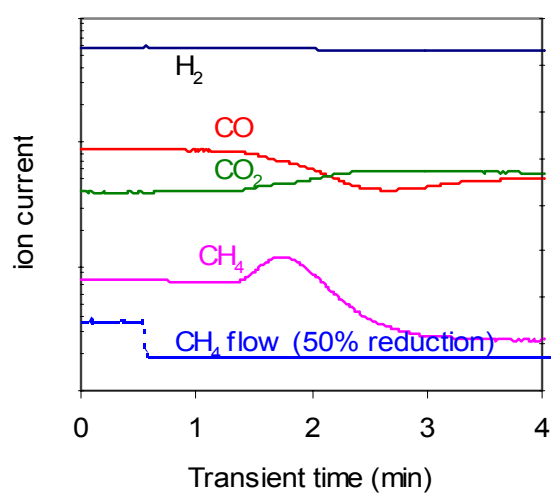

Figure 2. Transient response of Catalytica's sub-scale 1-kW_e prototype methane reformer

closely controlled. Other components in the fuel processor system include sulfur removal, water-gas shift, and preferential CO oxidation reactors. **Figure 2** demonstrates the transient response of a sub-scale 1 kW_e unit.

The University of Michigan plans to integrate low-cost microchannel systems, high activity catalysts, and high efficiency microcombustors/microvaporizers into a fuel processor. The microchannel design will allow efficient thermal integration of the fuel processor components leading to minimization or elimination of heat exchangers. Optimization of temperature profiles will lead to minimal catalyst bed size and reduced start-up and transient response times.

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