IV.B.5 Facility Development for Fuel Reforming R&D

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Objectives

- Develop a capability for test evaluation of 1-30 kW (thermal) endothermic or exothermic reformer technologies being considered in the NETL Solid State Energy Conversion Alliance (SECA) fuel cell development project. The test stand will be capable of a variety of fuel types (coal-derived fuels, diesel, jet fuels, gasoline, natural gas, etc.) and be capable of variable gas compositions to simulate anode recycle along with other system schemes.
- Modify an existing test rig (catalyst screening unit [CSU]) for multipurpose use in evaluating advanced fuel reforming concepts such as plasma-assisted reforming at a multi-hundred watt scale as technologies progress beyond laboratory scale development.

Accomplishments

- Completed the construction of a test stand capable of evaluating 1-30 kW (thermal) reformers on a continuous 24/7 basis on a variety of gaseous and liquid hydrocarbon fuels.
- Modified a smaller scale test rig to make it flexible to adapt to evaluate any new reforming technique such as plasma reforming, reactor configurations, etc.

Introduction

The U.S. Department of Energy's SECA program is sponsoring the development of high-temperature fuel cell power systems based on solid oxide technology. Many of the market applications for mass manufactured, high volume fuel cells rely on the use of hydrocarbon fuels. Several key characteristics desired for the processor (and the system) include; low cost, high efficiency, maximum thermal integration, low maintenance intervals, and acceptable startup and transient response. In addition, there are also several barrier issues that must be overcome to achieve these characteristics, which are generally applicable to all hydrocarbon fuels (gaseous, liquid, coal-based). Development and demonstration of this critical fuel processing technology is vital for the overall success and commercialization of the fuel cell technology. Therefore, the NETL's fuel processing facilities were established to explore fundamental and applied reforming research and development (R&D) issues that are inherent in catalytic and non-catalytic unit operations present in fuel cell power plants. These issues include: reaction kinetics, development of fundamental reforming activity and selectivity scales, mapping reforming catalyst coking regimes, understanding the mechanism of poisoning, improving sulfur and carbon tolerance of catalytic materials and identifying/developing novel processes that are more resistant to typical degradations. This report discusses the NETL fuel processing facilities in detail.

Approach

By providing a means to evaluate fundamental and applied fuel processing issues, the fuel reforming facility will aid the SECA program to meet its goal of developing cost-effective fuel processors for high temperature fuel cell systems based on solid oxide technology. Prototype reformer test capability (up to 30 kW thermal) will be provided by a new fuel processing unit (FPU) test facility in FY 2007. Technology evaluation/development beyond the laboratory-scale will be provided by modification of an existing facility (the CSU).

Results

The fuel reforming facilities are comprised of four bench-scale reactor systems, two reforming test rigs (catalyst screening unit and fuel processing unit), one Micrometrics catalyst characterization unit, and state-of-the-art analytical capabilities. These facilities were designed as fuel flexible such that natural gas, alcohols, coal-derived fuels, Fischer-Tropsch fuels, diesel, automotive gasoline and their surrogates may be utilized as feedstock.

Bench-Scale Reactor Systems

- Four identical high temperature and high pressure fixed-bed reactor systems. (A schematic of these reactor systems is given in Figure 1.) Two of the reactor systems are designed to operate 24/7 with

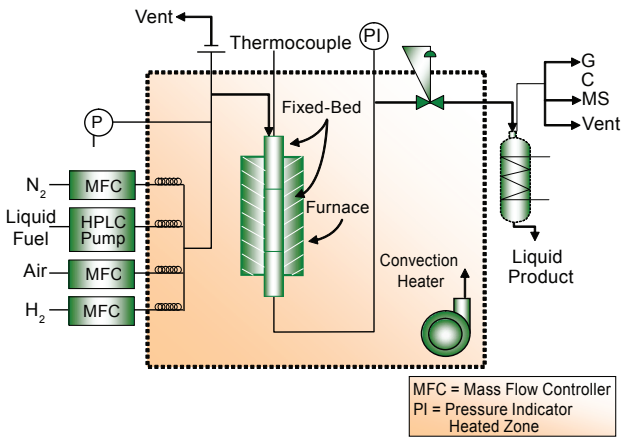

FIGURE 1. Schematic of Bench-Scale Reactors

FIGURE 2. Fuel Processing Laboratory with Twin-performance Reactors, Online Mass Spectrometer and GCs

unattended operation. Figure 2 shows two bench scale reactor systems with online mass spectrometer and gas chromatographs (GCs).

- Capability to run in different reforming modes such as autothermal reforming, partial oxidation, steam reforming and hydrodesulfurization of hydrocarbon compounds and the temperature programmed oxidation and reduction of catalyst samples.
- Reactor outlet streams are analyzed for the permanent gases as well as C1-C7 hydrocarbons using an online mass spectrometer and online gas chromatograph, respectively.

Reforming Test Rigs

- Capability to run in different reforming modes such as autothermal reforming, partial oxidation, steam reforming and hydrodesulfurization of hydrocarbon compounds and the temperature programmed oxidation and reduction of catalyst samples.

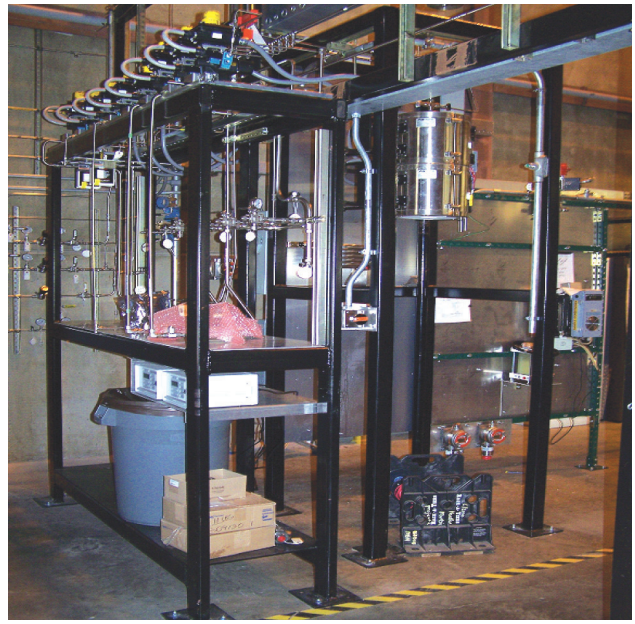

FIGURE 3. Fuel Processing Unit: A Test Stand Capable of Testing 10-28 kW Reformers

- Reactor outlet streams are analyzed for the permanent gases as well as C1-C7 hydrocarbons using an online mass spectrometer and online gas chromatograph, respectively.
- The CSU is a multipurpose and versatile research facility and can easily be modified for evaluating the advanced concepts for fuel reforming such as plasma-assisted reforming, temperature profiling of the catalyst bed during exothermic or endothermic reactions. The facility is rated in the multi-hundred kW range.
- The FPU has been designed and constructed for the purpose of testing 1-30 kW fuel processors developed by the NETL sponsored developers, such as those in the SECA program. The FPU may also be used during collaborations with other industrial developers through Cooperative Research and Development Agreements and is designed for 24/7 unattended operation. Figure 3 shows a side view of the FPU.

Catalyst Characterization Unit

- This unit performs N_2 Brunauer-Emmett-Teller surface area analyses, temperature programmed reduction, temperature programmed oxidation, temperature programmed desorption, surface titrations, and chemisorption experiments.
- Effluent gas can be analyzed using an online mass spectrometer.

Analytical Tools

- Fourier transform infrared spectroscopy and FT-Raman coupled.
- X-ray diffraction equipment.
- Scanning electron microscope.
- Inductively coupled plasma for catalyst composition analysis.
- Mass Spectrometer couple with gas chromatograph (flame ionization detector) (for $< C_{20}$ liquid hydrocarbon analysis).

Conclusions and Future Directions

An array of test and characterization facilities is required to properly evaluate and develop adequate fuel reforming technology. The fuel reforming facilities/capabilities at NETL are well-suited to accomplish the necessary R&D at various scales/stages needed to demonstrate commercial readiness and technology transfer. External developers and collaborators are encouraged to utilize the facilities to the extent possible to accomplish the goals of the program.