Overview of the NETL Onsite Fuel Cell R&D Program

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Introduction:

Onsite fuel cell R&D at the National Energy Technology Laboratory (NETL) has been ongoing since the late 1990's. The objective of the onsite program is to support development efforts of the fuel cell technology-related product lines and conduct fundamental research of advanced fuel cell technology. Of special focus is NETL's new 10-yr, multimillion dollar development program call the Solid State Energy Conversion Alliance (SECA). This program is aimed at developing low-cost mass manufactured solid oxide fuel cell technology for a wide variety of applications. In addition to SECA, there are a variety of other products/programs at NETL that can be supported by the onsite R&D group. Vision 21 is one such program and is the U. S. Department of Energy's initiative to deploy high efficiency, ultra-clean co-production coal conversion power plants in the twenty-first century. These plants will consist of power and co-production modules, which are integrated to meet specific power and chemical markets. In response to these program initiatives, NETL's onsite R&D group is developing significant capability and focusing current activity on the following areas:

1.) High-Temperature Fuel Cell Test & Characterization
2.) Integrated Fuel Processing
3.) Fuel Cell Component and Systems Modeling
4.) Sensors, Controls, and Instrumentation

The following sections will discuss plans and ongoing activities in each of these areas.

High-Temperature Fuel Cell Test and Characterization:

In 1999, NETL constructed a low-temperature 300-watt test stand that was used for evaluation of polymer electrolyte membrane (PEM) fuel cells. The facility was also used to evaluate the performance of DC/AC inverters that may be needed for various fuel cell applications. NETL is currently installing several high temperature test stands capable of testing at pressurized conditions and temperatures up to 1000°C. This facility, which is called the Solid Oxide Fuel Cell Experimental Laboratory (SOFCEL), will support R&D

of solid oxide fuel cells (SOFC) being pursued in the SECA program. These highly instrumented test stands (Figure 1) will be able to accurately characterize the performance and operation of single-cells and small stacks, as well lend themselves to developing a mechanistic understanding of the technology. Larger test stands up to 10 kWe are being planned to support the testing of fuel cell prototype systems being developed by the manufactures under the SECA program. Other test and evaluation opportunities are also being planned.

Figure 1: High-Temperature Test Stand

Integrated Fuel Processing

Over the past three years, NETL has been conducting a variety of activities focused on integrated fuel processing for high-temperature fuel cells. Much of the work evolved from NETL's long history in gasification and synthesis gas-related R&D. The primary focus is to build a core competency for on-site research to support NETL's fuel cell-related programs in addition to the gasification R&D. The following is a snapshot of some of NETL's onsite fuel processing activities:

Facilities/Capabilities: OST is currently working to complete construction on it's Fuel Processing Research Facility (FPRF). The FPRF (see Figure 2) is a multi-use platform capable of converting a gaseous or liquid hydrocarbon fuel into a tailored synthesis gas. I will produce up to 4000 scfh of gas at 900°C and 30 atm and is capable of supporting a 100 kWe fuel cell. The FPRP has multiple unit operations and can be used to evaluate a variety of fuel processing technologies such as reforming catalysts, desulfurizers, and separation membranes. A 3-yr CRADA was recently signed with UOP for the use and test of an advanced hydrogen separation membrane for the FPRF. Along with a complement of existing analytical equipment, OST is also completing a dedicated fuel processing laboratory that will be capable of conducting the necessary catalyst and sorbent R&D for liquid and gaseous hydrocarbon systems. This laboratory will allow hopeful continued support from OTT and other external organizations. In addition to the R&D facilities, OST is also planning to modify the FPRF (or add the SECA test stands) to allow for testing of 5-kWe fuel processors evolving from the SECA program. Most developers will independently test the fuel processor before coupling it to the fuel cell stack. This will give NETL the ability to provide this independent service for one of the most critical balance of plant items.

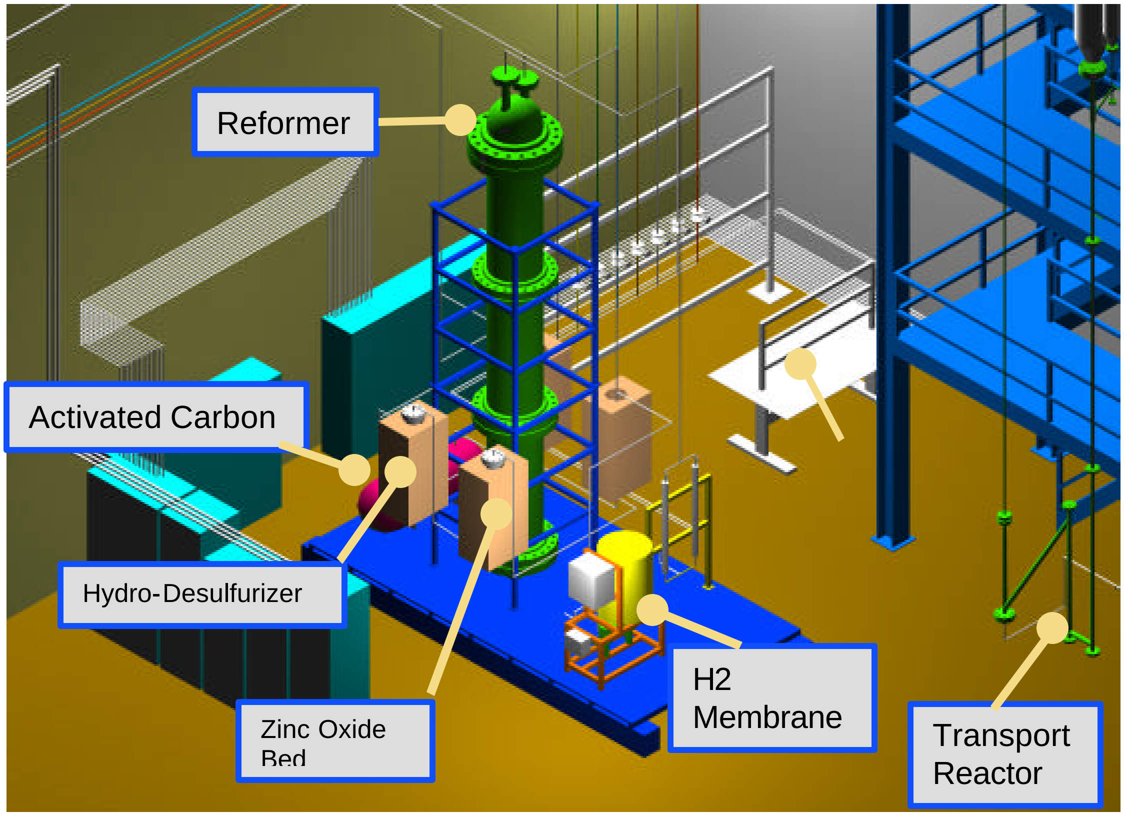

Figure 2: Fuel Processing Research Facility

System Studies: A number of system designs and evaluations have been conducted to assess fuel processing technology for a variety of applications. The systems analysis activity is a staple of the fuel processing program and provides a basis for evaluation and the conduct of technology R&D projects. Prior efforts involved the evaluation of a 4-MWe diesel fueled fuel cell system for the military. A state-of-the-art (SOA) system was defined, sized, and costed. Technology alternatives were then identified and an improved system was designed. A paper outlining this work was presented and published at the AIChE Spring National Conference (Berry 2001). The results of this study have helped shape the on-site fuel processing program. NETL is currently focused on evaluation and design of a novel 5-kWe fuel processor for a fuel cell APU. The effort is being funded in part by the Office of Transportation Technology and will be used to formulate much of the future fuel processing R&D program.

Desulfurization R&D: Sulfur-poisoning is a principal deactivation mechanism for both reforming and fuel cell catalysts. Unfortunately, sulfur is contained in most of the fossil fuels of interest including methane. NETL has been evaluating and conducting selected R&D for desulfurization (principally gas-phase) technology for both low and high temperature scenarios. One such technology, selected catalytic oxidation of hydrogen sulfide (SCOHS) allows for the direct cleanup of the fuel with byproduct elemental sulfur being formed. Several operational conditions and catalyst formulations were tested and evaluated. A paper outlining this work was presented and published at the ACS National Conference (Gardner 2001). Additional technology options were identified as a result of the systems analysis activity and literature searches. OST is also negotiating with a fuel cell developer for a CRADA to evaluate the viability of an NETL-developed (patent application made) desulfurization process for market-entry natural gas-based fuel cells.

Reforming R&D: OST is in the process of evaluating a novel reformer for the 5-kWe APU fuel processor. Various geometry's, materials of construction, and catalyst systems are being explored. Detailed stress analysis modeling will be utilized to evaluate startup and transient effects. As mentioned before, NETL is completing construction of a fuel processing laboratory that will contain multiple small-scale/micro reactors. This will allow characterization of diesel reforming catalysts for fuel cells not currently available in the literature. It will also provide a means to independently test catalysts being developed by other participants in the SECA program.

Fuel Cell Component and Systems Modeling

CFD Modeling of Fuel Cells: Many of the advances in fuel cell technology have occurred through experimental R&D efforts. While significant gains in performance have been made over the past 20+ years, to increase the likelihood of success in developing the next generation of fuel cells and fuel cell stacks, more sophisticated predictive models are desired. This project will provide developers with a tool that can predict the detailed, coupled, thermal, fluid and electrochemical phenomena present in fuel cells. It also will be able to predict the voltage/current field within the fuel cell mechanical structure. FY02 developments include internal reforming and improved diffusion transport. Stack analysis will also be examined. Upon successful resolution of the species, current, and thermal fields within the cell/stack, the solid-mechanic phenomena (stress-strain) will also be modeled. The later is a significant issue for high temperature ceramic technology. To verify the present code, NETL will be testing small 50 watt single cell specimens, as outlined in the SOFCEL project above.

Hybrid Modeling & Facility Development: Hybrid technology is an important research and development topic for NETL. This project has two main elements: dynamic modeling and experimental simulation. The latter project will simulate a fuel cell via a combustion unit that is configured to represent a hybrid system. The system uses an off-the-shelf ~75kW gas turbine (Figure 3). The experiment will provide needed technical data regarding the instabilities and component-to-component dynamic interactions present in hybrid systems. This project will also develop new modeling tools at NETL to help in the future design and operational understanding of hybrid technology. The most significant benefit from this work will be the identification and proposed resolution of critical technical issues faced by this new technology--e.g., how much more durable will the fuel cell components need to be?, what happens when a fuel cell trips and the entire fuel energy reacts within a downstream oxidizer?, what are the expected ranges of residual fuel components entering the oxidizer?, what new safety elements and controls need to added to reliably operate these new systems?, etc. As the main government support organization for stationary power fuel-cell development, it is important for NETL to understand these critical issues. The presence of an experimental hybrid simulation rig at NETL will help to secure both the needed technical information, as well as show that NETL In-House is capable of supporting this future technology.

Figure 3: 75 kW Turbine

Sensors, Controls, and Instrumentation

As fuel cell development progresses, the need for sensors, controls and instrumentation will continue to increase. There are many challenges in trying to apply technology in this area that include; high temperature environments, hydrogen-containing explosive gases, small flow channels, and limited ability to access cells/components to name a few. One technical approach is to use small, low cost, low-power micro-electro-mechanical-systems (MEMS). This approach has the potential to be mass produced at low cost using micro-machining processes. Application of the technology may reduce required external peripheral control components, extend cell life, and improve performance. One such application that NETL has been pursuing is to utilize MEMS to even out the maldistribution of flow that can occur within channels of cells within a fuel cell stack. Models are being developed and components are being fabricated to evaluate the potential of this technology.

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