IV.B.4 Liquid Hydrocarbon Fuel Reforming Studies

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Objectives

- Evaluate the use of plasma energy to reform heavy hydrocarbon fuels (e.g. diesel) into hydrogen-rich synthesis gas for fuel cells for use by high-temperature fuel cells being developed in the Solid State Energy Conversion Alliance (SECA) program.
- Conduct literature survey.
- Assess different liquid fuel introduction/mixing schemes.
- Evaluate effects of operating parameters on reformer quality.
- Complete the reactor setup to use the Drexel Plasma Institute (DPI) Reverse Vortex Plasma Reformer.

Accomplishments

- Design work for the DPI's Reverse Vortex Plasma Reformer is nearly complete with acceptance testing and delivery of the unit from Drexel University in Fall 2007.
- Conducted literature survey of plasma processes relative to plasma reforming. A draft report has been prepared for possible peer-reviewed publication.
- Performed shakedown runs in the catalyst screening unit in order to prepare it for DPI's Reverse Vortex Plasma Reformer. Successfully evaluated an ultrasonic nozzle for the liquid fuel introduction into the reactor. Also, studied several reactor configurations for diesel reforming.

Introduction

The successful deployment of fuel cell technology for many market applications requires the use of hydrocarbon-based fuels. The U.S. Department of Energy is sponsoring development of high temperature fuel cell power systems based on solid oxide technology through its SECA program. The fuel processor is a critical component of these systems and must be able to provide a clean, tailored hydrogen-rich synthesis gas to the fuel cell stack for long-term operation. There are a number of barrier issues that must be overcome in using hydrocarbon fuels. Carbon formation, both during startup and long-term operation, must be minimized to avoid coking of the catalysts in the reformer and downstream fuel cell. Also, most fuels contain some level of sulfur that can poison both the reforming catalysts and the fuel cell anode. Much of the technology development thus far has focused on catalytic systems. Although widely used in high steam commercial processes, most known catalytic-only systems are not capable of sustained reforming operation in low steam concentration (dry) reforming conditions. Oxide-based catalysts show some promise, but are unproven to at this point.

The use of non-catalytic processes such as plasma or thermal reforming needs to be evaluated and considered. Catalytic processes also may be enhanced by use of alternative approaches. For example, it may be possible to pre-treat the fuel in such a way as to saturate the aromatic and double-bonded carbons that are thought to be predominately responsible for carbon formation. In addition, alternative reactor materials, configurations, and schemes may play a significant role in resolving the carbon deposition issues surrounding these reformers. NETL will evaluate internally-generated ideas/concepts as well as selected external efforts.

Approach

Novel approaches or concepts are necessary for the development of robust fuel processors for the fuel cell systems. The use of non-catalytic process such as plasma reforming needs to be evaluated and considered. Low temperature non-thermal plasma can be a viable alternate to catalytic processes because of the absence of any catalyst that can be deactivated in the presence of highly complex diesel-like fuels. There are several articles in the open literature using plasma techniques to reform a simple hydrocarbon such as methane. However, technical as well as economic viability of the reforming of higher hydrocarbons such as diesel using plasma has yet to be established. Also, a series of different kinds of plasma techniques using different plasma discharge mechanisms are being used for reforming: corona, gliding arc, dielectric barrier, radio frequency and microwaves. Each of them has its advantages as well as disadvantages. However, we will explore the reverse vortex plasma reformer (uses a gliding arc discharge) for the reforming of hydrocarbon fuels such as diesel. This novel type of reactor design has a plasma discharge that is created and contained within a vortical counter-current flow-field. This reformer will be supplied by DPI of Drexel University, Philadelphia, PA.

This plasma reactor is designed to operate at a pressure of 15 psig and utilizes partial oxidation or steam reforming of methane or diesel fuel at different

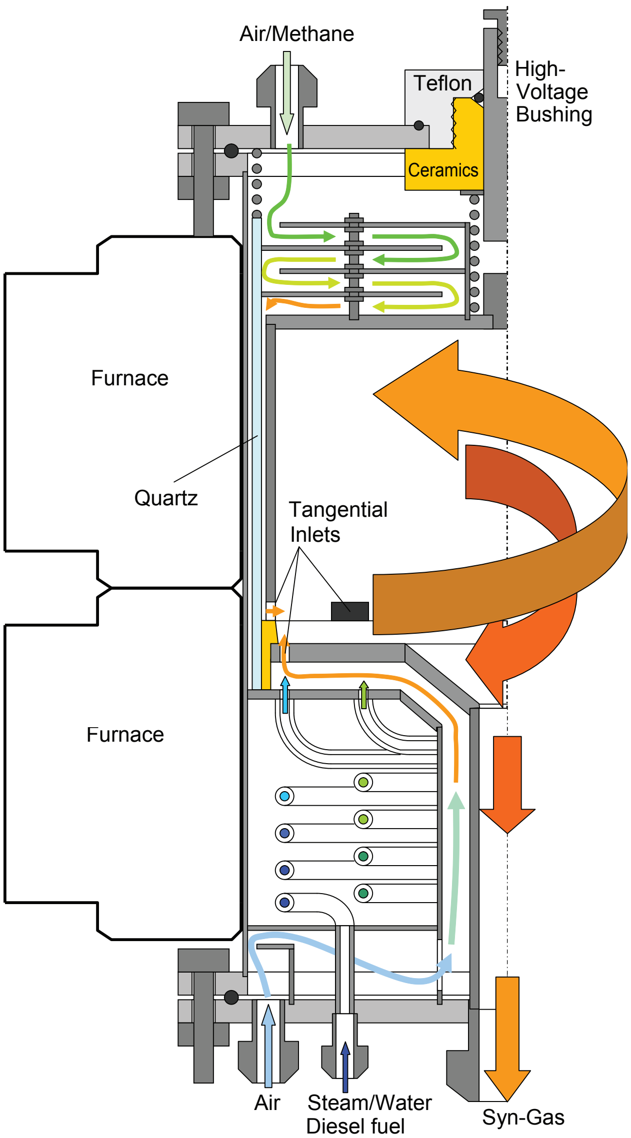

Figure 1. Overview of Plasma Reformer

oxygen-to-carbon ratios. Figure 1 gives a general idea of how the central core of the plasma reformer works as well as the locations of the input/output streams.

Results

Recently, in a research project supported by ChevronTexaco, DPI developed and patented plasma technology for methane conversion into syngas [1-3]. A special plasma system, gliding arc in tornado (GAT) reactor was developed for this technology [1-3]. Non-equilibrium plasma generated in the gliding arc has demonstrated the potential of combining the advantages of both thermal and non-thermal plasmas in optimized regimes. GAT is a source of non-equilibrium plasma for plasma-catalytic process of partial oxidation. This means that energy for chemical conversion is taken mostly from the process itself, and only a small portion (about 2%) is supplied by the plasma. The GAT system is especially promising for liquid fuel conversion, as the reverse vortex flow that stabilizes the plasma has a natural place for a second flow injection (for example, diesel fuel). According to the available information, absence of such place in conventional vortex reactors and resulting fuel coking are major reasons for significant delay in commercialization of the technology developed elsewhere.

The reaction vessel and lid of the plasma reformer are being designed to include an external window (in the top flange) which will allow us to view the interior of the plasma reformer. Two windows into the reactor, one on the reactor lid and the other window to be located on the top flange, will provide a view of the state of the discharge and location of reaction the flame. Both windows can be aligned so that it would be possible to see straight down into the reaction vessel when looking from the top of the vessel. This will provide an optical access into the plasma reformer for the plasma characterization measurements such as electron distribution and plasma density.

DPI has conducted some shakedown runs using methane as a fuel at partial oxidation conditions. Photos in Figure 2 are the view of plasma from top down into the reactor: (1) arc elongation and (2) gliding arc zoom. The plasma reformer is expected to be delivered to NETL in Fall of 2007.

Conclusions

Plasma technology provides an interesting and possible alternative for either full or assisted fuel reforming. A facility and reactor system has been established at NETL to allow for parametric evaluation of plasma processes with the DPI unit and/or other plasma developments efforts being undertaken to provide suitable hydrocarbon reforming for fuel cell based systems.

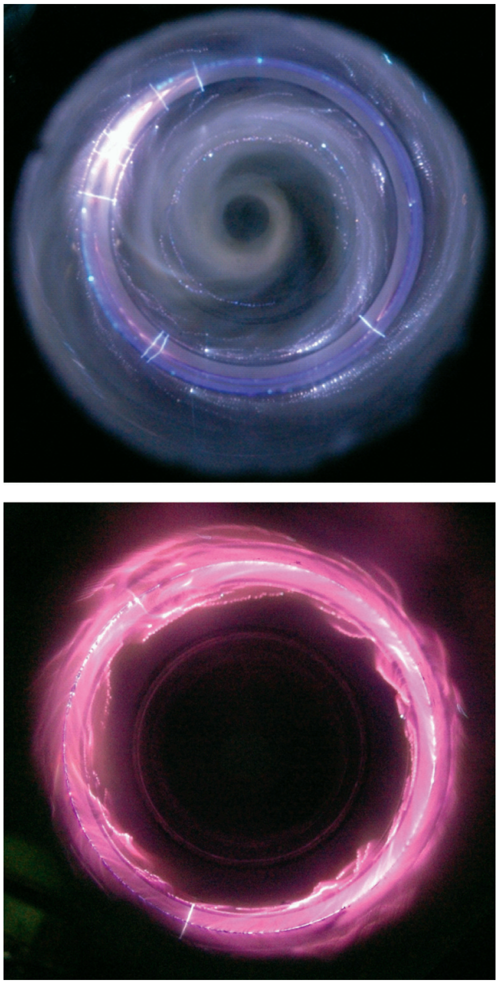

FIGURE 2. View of Plasma from Top Down into the Reactor: (1) Arc Elongation (2) Gliding Arc Zoom

FY 2007 Publications/Presentations

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2. C S Kalra, Y. I. Cho, A Gutsol, A. Fridman, T. S. Rufael, Gliding Arc in Tornado Using a Reverse Vortex Flow, Review of Scientific Instruments 76, 025110 (2005).

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