

# JP-8 REFORMATION FOR FUEL CELL APPLICATIONS

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## ABSTRACT

Military jet fuel (JP-8) has been successfully reformed to produce synthesis gas (hydrogen and carbon monoxide) selectively with a rhodium-based catalyst. Time-on-stream experiment indicates that the catalysts remains stable and active for at least 4 hours using a jet fuel (310ppm sulfur) straight from the pump without pre-reforming sulfur removal. The dry gas composition of the product (reformate) includes about 15 % hydrogen, 20% CO, 1% methane, 58% nitrogen and others. This JP-8 reformer can potentially be integrated with a reformate sulfur sorption bed and a solid oxide fuel cell for tactical power applications.

## 1. INTRODUCTION

A source of hydrogen has been the major technical barrier to utilize fuel cells as power sources in the Future Combat Systems. Reformers generate hydrogen by breaking down hydrocarbons through catalytic processes. An integrated system of a fuel reformer and a fuel cell can provide portable and mobile power for battery chargers and scout vehicle silent watch. In the past few years Schmidt and others have demonstrated the feasibility of reforming heavy hydrocarbons (e.g. octane, decane, and hexadecane) in a short contact time reactor (Krummenacher et al.). JP-8 is a complex mixture of heavy hydrocarbons with organosulfur impurities, and we need to study the capability of this reforming technology to convert JP-8 directly for fuel cell applications.

The objective of the present study is to develop advanced catalytic reforming materials and processes to utilize military JP-8 for solid oxide fuel cell (SOFC) applications. The catalytic partial oxidation converts the fuels in the presence of oxygen (from the air) to a mixture of carbon monoxide and hydrogen.



Since both carbon monoxide and hydrogen are the fuels for SOFC, a carbon monoxide removal step is not necessary. In addition to syngas (CO and H<sub>2</sub>) production, the reformer also converts over one hundred organosulfur impurities into a few inorganic sulfur compounds (mainly H<sub>2</sub>S). Pre-reforming and post-reforming sulfur traps are usually required to remove organosulfur and inorganic sulfur compounds, respectively.

## 2. EXPERIMENTAL

The jet fuel sample was a military JP-8 from Fort Belvoir. The fuel was collected at a fueling pump without any sulfur removal procedures before our reforming experiments. The fuel was analyzed independently with the Antek total sulfur analyzer and the Sievers sulfur chemiluminescence detector coupled with gas chromatography. Both analyses indicated that the fuel sample contains about 310 ppm sulfur.

The reforming experiments of the JP-8 were performed in a short contact time reactors similar to previous reports, but we built the reactor with a second fuel injector for water injection. We fed the fuel and the water into the quartz reactor through a preheat/mixing region. The catalyst was a rhodium-based catalyst supported on monolithic foam. We analyzed the reformate composition with gas chromatography. Since JP-8 was a complex hydrocarbon mixture, the conversion of JP-8 was estimated by assuming that all molecules bigger than C<sub>8</sub> are reactants. This estimation gave a lower bound to the fuel conversion, and the actual conversion was higher than the value reported here.

The time-on-stream experiments were performed in the same reactor system. Every 3 minutes the reformate

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was automatically sampled for gas analysis with an Agilent multi-channel micro gas chromatography.



Fig. 1 JP-8 reformer at Army Research Laboratory

### 3. RESULTS AND DISCUSSION

We have evaluated our reforming technology with a military JP-8 fuel from Fort Belvoir. This JP-8 contained about 300 ppmw sulfur. We built a dual-injector reactor to investigate the heavy hydrocarbon reformation under dry conditions or with steam addition. In steam addition experiments, we used steam-to-carbon ratio of 1 ( $H_2O/C = 1$ ). These steam addition experiments simulate recycling steam from SOFC. When the reformer is integrated with a SOFC, the  $H_2O/C$  ratio of 1 is the maximum  $H_2O/C$  ratio without addition of external water. Under dry conditions, the JP-8 conversion remained above 80% with a  $C/O$  ratio from 0.7 to 2.0. At low  $C/O$  ratio the main products were hydrogen and carbon monoxide, while at high  $C/O$  ratio the main products were olefins. Since the preferred fuels for solid oxide fuel cells are  $H_2$  and  $CO$ , one would like to run a  $C/O$  ratio of 0.7 or 0.8 for fuel cell applications. With steam addition ( $H_2O/C = 1$ ), the JP-8 conversion remained high for  $C/O < 1.3$ . The catalytic temperatures with steam addition were typically lower than the catalytic temperatures under dry conditions by 100-150°C. Catalyst temperatures of 750°C were too low to sustain 80% fuel conversion. Steam addition also reduced the undesired carbon deposition.

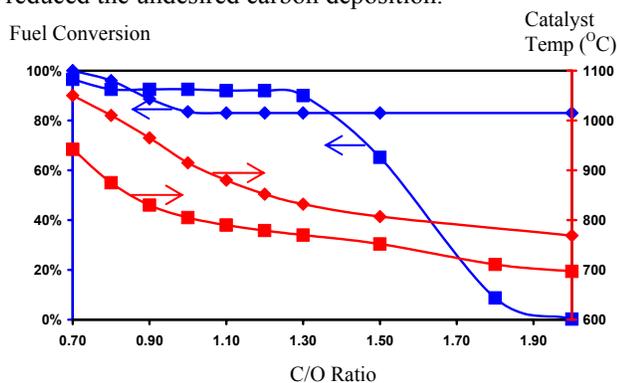


Fig. 2 JP-8 reformation with  $H_2O/C = 0$  [♦] or  $=1$  [■]

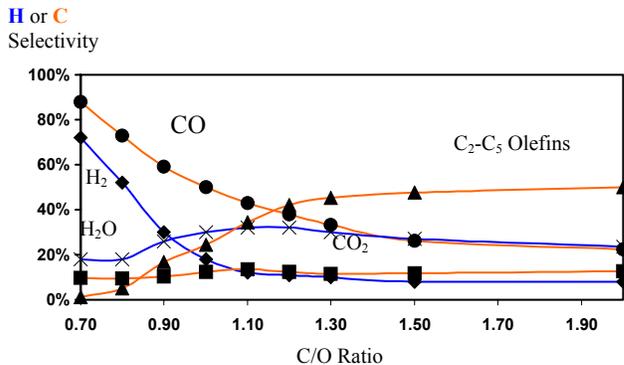


Fig. 3 Low  $C/O$  ratio favors hydrogen generation for SOFC

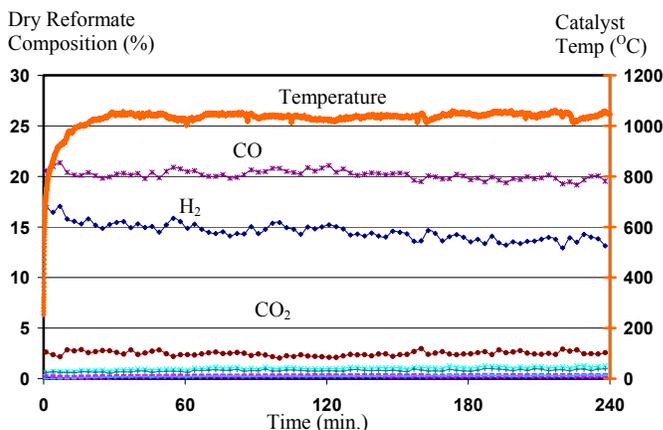


Fig. 4 Time-on-stream experiment for JP-8 reformation under dry conditions.

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### CONCLUSIONS

We have demonstrated the feasibility of reforming a military JP-8 directly without pre-reforming sulfur removal. We can tune the JP-8 reformer to produce hydrogen selectively. Our reforming technology gives high yields of  $CO$  and  $H_2$  for solid oxide fuel cell APU applications. Reformation studies of long term durability and sulfur tolerance limits are in progress.