

**ELECTROCHEMICAL CONVERSION OF COMPLEX FUELS TO
ELECTRICAL ENERGY**

PROGRAM SOLICITATION NSF 09-609

GRANT NUMBER 1012707

1. Introduction

The research objective under the present effort was to lay the foundation for a novel fuel cell that does not require the conversion of a complex fuel into hydrogen prior to its use. Prior to this effort, to use complex fuels directly required one or more of the following to be included in the system: chemical conversion of the complex fuel to a simple mixture containing the hydrogen; catalyst materials resistant to poisoning by fuel impurities; complex purification methods and/or high operating temperature. The program researched the effectiveness of stabilizing the fuel cell performance by separate electrical means and effecting the direct conversion of a complex fuel to electrical energy in a fuel cell device designed specifically for the purpose. The cell design was tested in a single cell assembly using fructose as the test fuel. A parallel effort was directed at validating the cell design assumptions by using hydrogen with specific levels of impurities.

2. Research Plan

The cell design has three electrodes. Two electrodes supply the power for the load; two electrodes are used for controlling catalyst activity to reverse the deleterious effects of fuel impurities and reaction intermediates. One method uses a small electrical potential to control - bias - electrode activity. The Phase I effort concentrated on the following tasks:

- Experimental verification of potential bias effectiveness at removing adsorbed carbon monoxide (CO), a known poison for platinum based catalyst.
- Experimental evaluation of the effect of operating temperature on cell performance with fructose fuel.
- Experimental evaluation of the effect of fuel concentration and chemical make-up on cell performance.

3. Research Results Summary

Task one findings confirmed that the bias preserved catalyst activity at CO concentrations beyond what might be expected from a reformer outlet stream. Removing the bias caused the performance to drop precipitously. The proof-of-concept data shows that, with the bias applied, the cell performance is stable and essentially the same as before the

introduction of carbon monoxide. The bias level required to stabilize the load performance is low relative to the load current, less than ten percent. In the absence of bias, the performance is rapidly affected by the CO. The bias was also effective at restoring the cell performance even when it was applied after the poisoning had already taken place.

The proof-of-concept results have immediate significance for the future of this technology: fuel cell power systems using reformer fuel can benefit from simpler system requirements by switching from catalytic CO removal to a biased cell configuration. Electrical means of controlling cell performance is faster and effective at lower temperatures than the alternatives. Portable systems or those which undergo repeated start-stop cycling could benefit the most from this development. These results represent a potentially significant development for large scale fuel cell power generation.

The data collected from testing with fructose allowed a preliminary assessment of the optimum bias level for the operating conditions. The applied bias is an energy expense taxing the system efficiency. Although higher cell current output improves the system energy efficiency – the optimum for all operating conditions is the lowest bias potential which produces stable performance.

The effect of temperature on cell performance was as anticipated. At 120°F the slope of the polarization curve is less than half that at ambient. However, the bias current was also higher and the rate of secondary reactions increased as well. Overall, temperature has a positive effect but requires better characterization of the fuel chemistry.

Beyond a certain threshold, the concentration of the fuel solution does not seem to impact the cell electrical performance. Conversely, the cell can process dilute fuel solutions quite effectively. Higher dilution also helps to avoid unwanted secondary chemical reactions (chemical degradation of the fuel) which would have deleterious effects on the cell operation.

The present effort establishes a new direction for development of electrochemical cells. It is a method and a tool to approach many applications presently considered beyond the practical reach of electrochemical technology.

Organic matter is the depository of a large amount of energy. Electrochemical conversion is the most efficient path from chemical to electrical forms of energy and yet this path was mostly closed because of catalyst inadequacy relative to performance requirements. The research summarized in this report offers experimental support to the argument that new ways and original electrochemical cell designs could bring vast new energy resources within the reach of modern society.