

V.J.3 Large Scale Testing, Demonstration and Commercialization of Nanoparticle-Based Fuel Cell Coolant

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Contract Number: EE00004532

Subcontractors:

- University of Tennessee, Knoxville, TN
- Protonex Inc., Southborough, MA

Project Start Date: October 1, 2010
Project End Date: September 30, 2013

(A) Durability

(B) Cost

Technical Targets

Dynalene's fuel cell coolant (Dynalene FC) is expected to help the fuel cell industry achieve their durability and cost targets to some degree. First of all, the coolant itself is being designed to have a life of 5,000 hrs. It is also expected to have excellent compatibility with the system materials and inhibit corrosion in the coolant loop. This will help in extending the durability of the fuel cell system components such as the pump, the radiator, valves, seals/gaskets and any other components coming in contact with the coolant. The coolant is also designed to work at -40°C, which will assist both transportation and stationary fuel cells to quickly warm up during cold starts.

The cost target for the coolant (in plant-scale production) is about \$10/gallon, which is very close to the retail price of current automotive coolants. This coolant will also eliminate the de-ionizing filter and other hardware associated with it (i.e. fittings, valves). It is also being designed to work with cheaper, lighter and thermally efficient components such as aluminum radiators (instead of stainless steel) and brass heat exchangers.

Fiscal Year (FY) 2011 Objectives

The overall objective of this Phase III Small Business Innovation Research project is to demonstrate the 5,000 hr durability of the nanoparticle-based coolant fluid developed in Phase I and II, and perform further research into how durability is affected and how to improve it. The specific objectives are:

- Validate 5,000 hr durability of the coolant fluid by developing long-term test plans in-house as well as in subcontractor locations.
- Study the effect of nanoparticle properties on its durability under severe conditions such as thermal cycling, high electric field and presence of contaminants.
- Determine the efficiency of corrosion inhibitors in long-term tests under severe conditions.
- Increase the nanoparticle surface charge to >500 µeq/g for both cationic and anionic particles.
- Perform testing of the coolant samples by fuel cell companies and begin commercialization.

Technical Barriers

This project addresses the following technical barriers from the Fuel Cells section (3.4.4) of the Fuel Cell Technologies Program Multi-Year Research, Development and Demonstration Plan:

FY 2011 Accomplishments

This project was originally awarded on a conditional basis until all the financial audits by the DOE were complete. The project started to gain momentum when the final contract was signed in March 2011. The following are the accomplishments:

- Design of the fuel cell system to test Dynalene coolant at the University of Tennessee (UT) facility is complete and parts are ordered.
- Dynalene completed negotiations with Protonex who is building a fuel cell system to supply to Dynalene. Protonex also will test the final coolant (after optimization) for >5,000 hours in one of its systems.
- Dynalene has performed preliminary glassware corrosion tests and has demonstrated the effectiveness of inhibitors towards aluminum and brass.



Introduction

This project addresses the goals of the Fuel Cell Technologies Program of the DOE to have a better

thermal management system for fuel cells. Proper thermal management is crucial to the reliable and safe operation of fuel cells. A coolant with excellent thermo-physical properties, non-toxicity, and low electrical conductivity is desired for this application.

An ideal coolant must be durable for >5,000 hr of operation, and therefore, the coolant must be tested for such duration. Electrical conductivity of the coolant should be less than 10 $\mu\text{S}/\text{cm}$ throughout the testing period and the coolant must be compatible with all the materials (metals, plastics, rubbers and composites) at the highest operating temperature. Current automotive coolants do not satisfy the electrical conductivity criteria due to the presence of ionic corrosion inhibitors in them. Water/glycol solutions without inhibitors can have low starting electrical conductivity, but it can increase rapidly due to corrosion of metal components leading to build-up of ions in the coolant. Fuel cell developers are using water or water/glycol mixtures with a de-ionizing filter in the coolant loop. The filter needs to be replaced frequently to maintain the low electrical conductivity of the coolant. This method significantly increases the operating cost and also adds extra weight/volume to the system.

Dynalene Inc. has developed and patented a fuel cell coolant with the help of DOE Small Business Innovation Research Phase I and Phase II funding (Project # DE-FG02-04ER83884). This technology has been patented in the United States, Canada and Europe. The technical feasibility of this coolant was demonstrated in short-term tests using a dynamic re-circulating loop. The nanoparticles used in the coolant were optimized for size and surface charge density.

Approach

In this Phase III project, Dynalene's plan is to validate the durability of the coolant fluid by developing long-term test plans in-house as well as in subcontractor locations. Nanoparticle-based coolant will be subjected to severe conditions such as thermal cycling, high electric field and presence of contaminants. Efficiency of the non-ionic corrosion inhibitors in long-term tests will be evaluated using electrochemical and glassware corrosion tests. Further research will be dedicated to increase the surface charge density of the nanoparticles. Lastly, samples will be sent to fuel cell companies (including subcontractors) for long-term testing and Dynalene's business development team will start the commercialization effort.

Results

A representative fuel cell coolant and heat rejection system was designed by UT

researchers to accurately simulate the environmental, material, and operational conditions experienced in full-sized fuel cell systems. The ultimate goal is to enable Dynalene to more rapidly develop next generation coolants for fuel cell systems and provide potential customers with application specific independent validation of the benefits of the Dynalene coolant product. Additionally, fundamental understanding of the key controlling parameters that result in ionic impurity contamination within typical coolant subsystems will be determined.

The testing facility designed by UT researchers will emulate the conditions of coolant in an operating fuel cell. Figure 1 shows a schematic of the test system as designed along with the chosen components. Since the project contract was only recently made official, the design of the test rig is complete, and parts will be ordered as soon as the final internal paperwork is completed shortly. The experimental test system will include an operating fuel cell with fully functional coolant flow plate designs, coolant pump, and interchangeable lengths of chosen materials that will be in contact with the coolant. Since the fuel cell will not be a full size stack, an appropriate heat load will be applied to the flow entering the fuel cell to simulate fuel cell stack operating temperature. The system is designed so that different material exposures can be easily implemented by changing component piping materials and lengths. A real fuel cell system radiator will be obtained from industrial suppliers, and has been arranged through Dynalene. Species extraction as shown will enable ex situ measurement of the fluid contents and a variety of important diagnostics to be taken to reveal the key controlling parameters in the degradation of coolant performance. Diagnostics will monitor the coolant system pressure drop, electrical

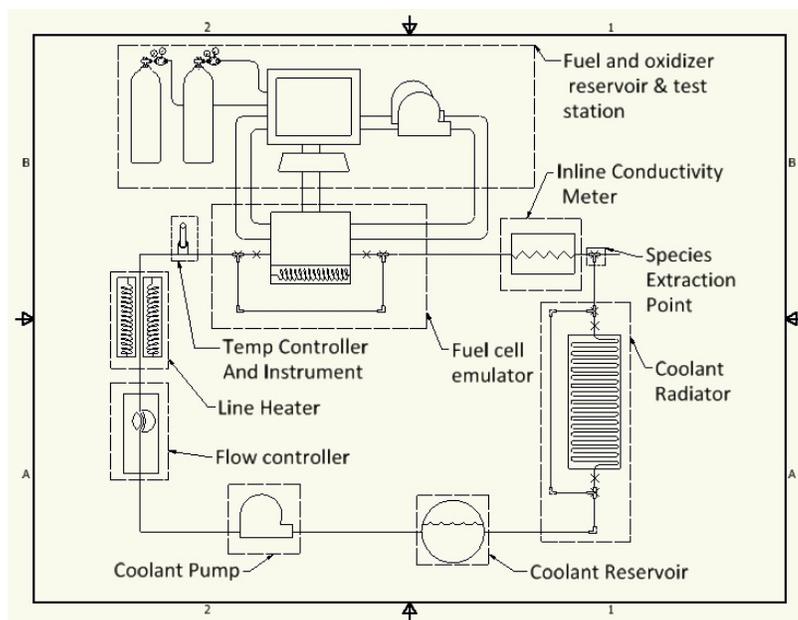


FIGURE 1. Schematic Diagram of the Fuel Cell Coolant Test System at UT

conductivity, flow rate, and heat capacity of the coolant as a function of operating conditions including temperature, coolant flow, and electrical load. A coolant bleed off valve will be installed to allow ex situ evaluation of the type and quantity of contaminants entering the coolant as a function of operating parameters. Both metal and graphite bipolar plate designs with material and coatings purchased from known suppliers and used in operating systems will be integrated into the test system, which will help identify the source of corrosion components. Ex situ surface examination by energy dispersive X-ray spectroscopy, scanning electron microscopy, and other spectroscopic methods will be used to visualize and reveal the composition of local ionic impurities. When complete, this test bed will be validated using different coolant fluids doped with controlled levels of conductive impurities, and the diagnostic systems will be evaluated and calibrated before regular testing.

Dynalene has conducted preliminary corrosion tests using aluminum and brass coupons. These metal coupons were tested in de-ionized water, ethylene glycol/water, propylene glycol/water and Dynalene's fuel cell coolant, Dynalene FC. The tests were conducted in glass jars at 80°C. Figure 2 shows the pictures of these coupons after 350 hours and 700 hours of exposure to the fluid. When they are compared to the control (untested coupons), it is clearly evident that the Dynalene FC fluid has the least corrosive effect towards the metal coupons. It is due to the presence of the non-ionic corrosion inhibitors.

Protonex Inc. has provided Dynalene with a scope of work on how they will test the coolant samples in their fuel cell system. Protonex also will provide a fuel cell system to Dynalene (to be installed at Dynalene's facility) for several long-term tests including 5,000-hr tests. The details of the project and the costs are already worked out. A photograph of the system is shown in Figure 3.

Conclusions and Future Directions

A fuel cell coolant test system has been designed by the UT team that will study the effect of thermal cycling, electric field and the presence of contaminants. Dynalene is preparing various samples of the coolant and performing corrosion and compatibility testing. Preliminary results showed that the corrosive effect of the coolant towards aluminum and brass is much lower than de-ionized water, propylene glycol/water, and ethylene glycol/water. A fuel cell system is being built by Protonex that will be used at Dynalene's facility for 2,000 and 5,000 hr tests.

UT is in the process of ordering all the parts for its test system. Assembly of the system should take place in the next few weeks and should be finished in August. Dynalene will supply three different variations of the coolant for testing. Dynalene will also continue the corrosion and compatibility testing with different system materials. At the same time, samples will be sent to fuel cell developers for

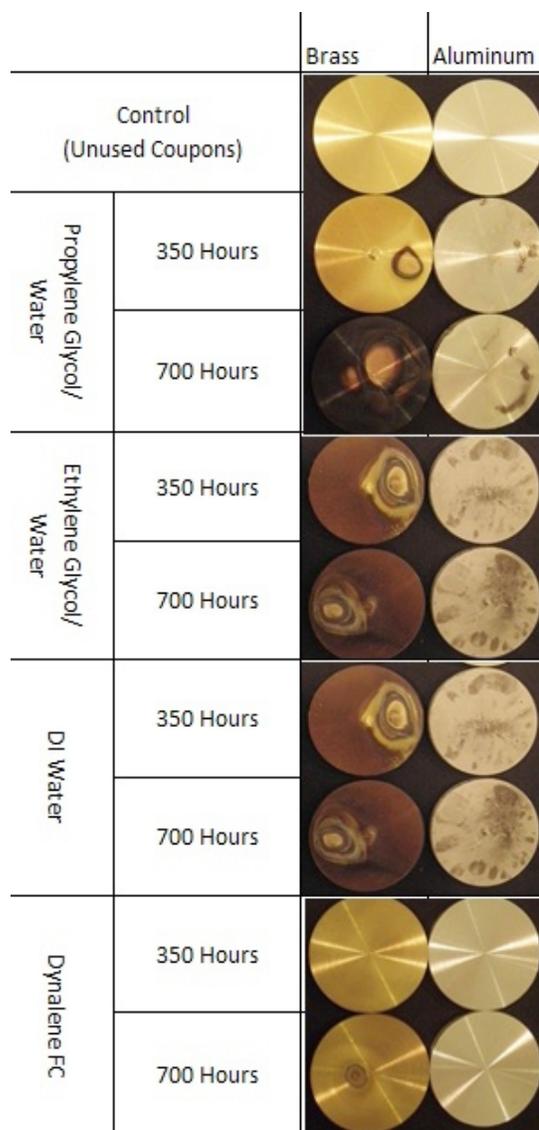


FIGURE 2. Aluminum and Brass Corrosion Testing in Various Coolant Fluids



FIGURE 3. System Photograph

testing in their systems. Feedback from time to time will help Dynalene researchers to optimize the coolant further.

FY 2011 Presentations

1. McMullen, P, Mock, J and S. Mohapatra, “Fuel Cell Coolant Optimization and Scale-up”, Poster presented at the Annual DOE Hydrogen Program Review Meeting, May 2011, Washington, D.C.