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14. ABSTRACT Extensive testing of the breadboard system was completed including baseline leak rate measurements. Several improvements were made to the system to permit stable, automated operation at 4 kilowatts, twice the previous power output, and the system was demonstrated at this power output. The first round of bench-top hydrogen recovery reactor media testing was completed. The supplier's procurement efforts for the final deliverable of the hermetically-sealed scroll compressors were underway.											
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Quarterly Progress Report

Project Title: Improved Round Trip Efficiency for Air Independent Regenerative Fuel Cell Systems

Project Period: June 18, 2010 to February 12, 2012

Date of Report: January 15, 2012

Recipient: Proton Energy Systems

Award Number: N00014-10-C-0369

Working Partners: W. L. Gore, AirSquared

Cost-Sharing Partners: None

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Project Objective:

The purpose of this phase of the effort is advance the understanding, implementation, and operational testing of the features that enable a regenerative fuel cell (RFC) to simultaneously be truly air independent and have high energy density. In addition, follow-on work is expected to investigate advanced membrane materials that enable higher efficiency electrolysis, substantially improving the practical energy density for RFC applications.

Objectives:

- Upgrade RFC system to enable full 4.4 kW fuel cell power output (previous system operated at 2 kW)
- Demonstrate improved closed loop capability through reduction of known mass losses: development of hydrogen recovery reactor and hermetically sealed compressors
- Perform durability testing on the existing RFC breadboard and refine startup and shutdown control systems

Background:

Navy underwater vehicle platforms (UUV, ASDS, SWCS, etc.) are demanding larger and larger energy storage capacities to accommodate longer underwater missions and increased platform power requirements. New energy storage devices with high volumetric energy density for underwater vehicles, both manned and unmanned, are therefore needed, such as regenerative fuel cell (RFC) systems based on proton exchange membrane (PEM) technology. An RFC consists of a fuel cell powerplant, an electrolysis system for recharging the reactants, and reactant storage. These water-

based energy storage systems have been shown to perform substantially better than traditional battery systems in areas such as rechargeability, specific energy density, and reliability. Advanced membrane and catalyst materials will enable higher efficiency electrolysis, substantially improving the practical energy density for regenerative fuel cell applications.

From a full proposal to develop an advanced demonstration system, Task 5 was selected for initial study. This task focused on membrane development and was reported on previously. The next step addressed operation of Proton's regenerative fuel cell system at the full 4.4 kW fuel cell design point and in a truly closed loop mode. The research objectives for Phase 2 of this task were broken into the following separate subtasks:

Task 2: Air-Independent RFC Component Durability Testing

Subtask 2.1: Re-commissioning of the existing RFC system

The contractor shall perform repairs and maintenance to the existing RFC system to achieve operability. Testing at relevant power density shall be initiated and baseline mass losses shall be measured.

Subtask 2.2: Upgrade fuel cell output capability

The contractor shall perform design work to determine requirements for doubling the fuel cell output capability. Upgraded components shall be installed and testing shall be performed at higher output power.

Task 3: Dissolved Hydrogen Recovery Reactor

The contractor shall design a hydrogen recovery reactor targeting 2,400 psi capability and build a prototype for integration into the RFC system. The contractor shall perform measurement of mass loss at up to 400 psi in order to compare to the baseline measurement.

Task 4: Hermetically Sealed Reactant Circulation Compressors

Improved scroll compressor prototypes shall be specified, procured and tested. The contractor shall integrate the new compressors into the RFC breadboard for testing.

Status:

Extensive testing of the breadboard system was completed including baseline leak rate measurements. Several improvements were made to the system to permit stable, automated operation at 4 kilowatts, twice the previous power output, and the system was demonstrated at this power output. The first round of bench-top hydrogen recovery reactor media testing was completed. The supplier's procurement efforts for the final deliverable of the hermetically-sealed scroll compressors were underway.

Task 2: Air-Independent RFC Component Durability Testing

Subtask 2.1: Re-commissioning of the existing RFC system

Diagnosis of the problem related to fuel cell voltage shutdowns was completed. One of the electronic load banks was malfunctioning. Replaced the load and the original fuel

cell stack. Multiple fuel cell and electrolysis cycles were completed with fuel cell power output at 2 kilowatts. Baseline leak rates during fuel cell and electrolysis operation were measured.

Subtask 2.2: Upgrade fuel cell output capability

In testing the fuel cell at higher power output (4 kW) it became clear that there were two system limitations. The first was the method of heat removal. It relied on the injection and mixing of fluid from a separate cooling loop into the fuel cell coolant loop. This configuration was replaced with a tube-in-tube heat exchanger which allowed the loop pressures to be decoupled and made it much easier to maintain the specified internal pressures within the fuel cell stack. The second problem was the control of the input reactant pressure, particularly on the oxygen side of the cell. The regulators present in the system could not maintain the pressure within a tight enough range over the operation at the low end and high end fuel cell power output. For the initial 4 kW testing, this shortcoming was overcome with manual adjustments of the regulator as the fuel cell load was increased. An automated solution was identified utilizing a motorized needle valve in parallel with the oxygen regulator to trim the pressure back up at higher power when the regulator began to droop. The automated solution was implemented with the hardware and a PID control loop added to the system controls. As a result, more consistent, automated runs at 4 kW were completed. Finally, a more accurate continuous level sensor was installed in the water tank and calibrated to provide additional data on the system leak rates.

Task 3: Dissolved Hydrogen Recovery Reactor

The 2,400 psi capable pressure reactor vessel was installed into the breadboard test system to be used as a water polishing bed. The reactor media will be replaced with the hydrogen recovery media when the bench-top tests are completed. The bench-top, sub-scale operational test system was built and commissioned. The initial round of tests on the candidate media was completed. Based on the initial round of tests, two additional tests were identified, and materials were prepared to allow the completion of those tests. Furthermore, bed-sizing calculations were performed to guide the expectations of performance both in the bench-top reactor tests and in the full-size system.

Task 4: Hermetically Sealed Reactant Circulation Compressors

Subcontractor AirSquared initiated procurement of their raw materials. They discovered an oversight in one component, a magnetic drive coupler, that was not made with compatible materials on all sides. Procurement of the correct pieces was initiated. The requirements for the motor drive were defined and confirmed. Motor drive components were specified, quoted, and ordered.

Task 1.0 Project Management and Reporting

The 5th quarterly report was prepared and submitted on October 15, 2011. A teleconference was held with ONR and Proton personnel on December 15, 2011.

Plans for Next Quarter and Key Issues:

Material procurement and fabrication of the hermetically sealed scroll compressors will be completed. When the scroll compressor assembly is complete and delivered to Proton, incorporation into the breadboard system will begin. In the next quarter, measurements of system losses in electrolysis and fuel cell modes of operation will be taken in the final configuration including the sealed compressors.

Patents: None to date.

Publications / Presentations:

A status update presentation was given to the ONR team in December.

Task Schedule

Task Number	Project Milestones	Task Completion Date				Progress Notes
		Original Planned	Revised Planned	Actual	Percent Complete	
2	Complete test stand refurbishment	8/10/11		8/31/11	100%	Completed installation and start-up
2	Complete baseline testing of recommissioned unit	8/31/11		9/30/11	100%	Initial testing in fuel cell and electrolysis modes
3	Complete hydrogen recovery reactor testing	10/15/11	1/30/12		75%	Materials for scale-up ordered
4	Procure hermetically sealed compressors	11/1/11	1/15/12		50%	Supplier procurement under way (delayed)
2	Complete upgrade fabrication/installation	11/30/11	12/10/11	11/15/11	100%	Complete
2	Initial multi-day full power testing	12/10/11		12/8/11	100%	Complete
1	Project Management				80%	

Budget Summary

Quarter	From	To	Estimated Billing	Actual Billing
2Q11	04/01/11	06/30/11		\$219,352
3Q11	07/01/11	09/30/11		\$285,617
4Q11	10/01/11	12/31/11		\$168,130
1Q12	01/01/12	03/31/12	\$146,810	
		Totals=	\$146,810	\$673,099

Total Program: \$819,909