II.B.6 High-Capacity, High Pressure Electrolysis System with Renewable Power Sources

Martin A. Shimko
Avãlence LLC
1240 Oronoque Road
Milford, CT 06460
Phone: (203) 874-6786; Fax: (203) 878-4123
E-mail: mas@gasequip.com

DOE Technology Development Manager:
Roxanne Garland
Phone: (202) 586-7260; Fax: (202) 586-2373
E-mail: Roxanne.Garland@ee.doe.gov

DOE Project Officer: Jill Sims
Phone: (303) 275-4961; Fax: (303) 275-4788
E-mail: Jill.Sims@go.doe.gov

Technical Advisor: Jamie Holladay
Phone: (202) 586-8804; Fax: (202) 586-2373
E-mail: Jamie.Holladay@ee.doe.gov

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Subcontractor:
HyPerComp Engineering, Inc., Brigham City, UT

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Estimated Project End Date: June 1, 2011

Objectives

In this project Avãlence is proposing to develop an enlarged version of our present design that will have 15x the capacity of our single tubular cell. This will be accomplished by first testing a cell at 1,000 psi using conventional pressure containment materials. We will then fabricate and test a single cell at 6,500 psi that uses composite fiber wrapping to achieve the pressure containment. We will then build a sub-scale system containing about 20 cells that will produce about 30 kg/day. After a three month period testing at the National Renewable Energy Laboratory (NREL), this system will be installed in revenue service in Portland, Maine.

Project Objectives

- Achieving at least a 15x increase in the gas production rate of a single high-pressure production cell.
- Demonstrate the high-pressure cell composite wrap which enables significant weight reduction.
- Build and test a 1/10th scale pilot plant.
- Have fabrication-ready drawings for full-scale plant (300 kg/day, 750 kW).

Project Technical Objectives

- Determine a manifolding and sealing arrangement for nested cell that satisfies need for H_2 and O_2 gas separation, electrical connection to electrodes, and electrolyte replenishment.
- Determine containment penetration size and design that is compatible with composite wrapped vessel constraints, cell electrode current transfer and flow requirements for gas off-take and electrolyte replenishment.
- Design a functional shape of outer metal jacket for dual purpose:
    1. Outer electrode's inner surface
    2. Vessel liner that is the foundation for composite wrap
- Demonstrate the performance of the nested cell core so that accurate projections of energy use can be integrated into the cost model.
- Demonstrate the ability to implement a composite fiber outer wrap over the nested cell core.
- Produce a pilot plant design for use as a basis for a sound economic analysis of plant fabrication and operating cost.
- Demonstrate the operation and efficiency of the pilot plant:
    1. Laboratory testing at Avãlence
    2. Field testing at NREL
- Have a site ready to accept the completed plant for commercial operation:
    1. 100 kW of renewable power in place
    2. Sale or use of the plant products defined

Technical Barriers

This project addresses the following technical barriers from the Production section (3.1) of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan:

(G) Capital Cost
(H) System Efficiency
(J) Renewable Electricity Generation Integration (for central)

Technical Targets

The goal of this project is to demonstrate the technology and estimate the production, efficiency, and operating cost of a 300 kg/day system. The assumption is that 5 modules will be used to achieve the 1,500 kg/day level used by DOE in their cost analysis and target cost definitions. The analysis uses a 20 year useful life and annual operating cost estimates of 5% of capital cost. Electricity costs of 3.9 cents/kWhr and an availability of 90% are also used.

Characteristics	Units	2012/2017 Targets	Avãlence Status	Avãlence Commercial Projection
Hydrogen Cost	\$/ kg H_2	3.70/<3.00	4.38*	2.84*
Electrolyzer Capital Cost	\$/kg H_2	0.70/0.30	0.98*	0.33*
	\$/kWe	400/125	2,600*	860*
Electrolyzer Energy Efficiency	% (LHV)	69/74	65*	70*

*Includes capital cost/energy of compression process
LHV – lower heating value

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Introduction

Avãlence has existing technology that is globally unique in its ability to deliver hydrogen directly at storage-ready pressures up to 6,500 psi without a separate compressor. Using an alkaline electrolyte process these Hydrofiller systems integrate the production and compression processes by operating the electrolytic cells at the desired delivery pressure. The systems can interface directly with renewable electricity supplies and have been shown in previous work that the electrolyzer operates through the full range of voltages output from the connected photovoltaic (PV) array without using any power conditioning equipment. These characteristics result in a renewable hydrogen production and delivery system that is significantly more efficient and reliable, and substantially less expensive than existing commercially available electrolyzer/compressor sets.

These smaller scale Hydrofillers are based on a single cathode/anode tubular cell design with production capability of about 0.1 kg/day. Using the present configuration, this technology is utilized in units (modules) with capacities of up to 10 kg/day by using arrays of individual cells in groups of up to 96. Though effective for small-scale, distributed hydrogen production, 150 modules would be needed to achieve DOE's 1,500 kg/day target for cost comparison. It is unlikely that this ganging of small electrolyzers can meet DOE's cost targets because of the immense interconnecting tubing requirement, excessive replication of the single cell (15,000), and wasteful repetition of the balance-of-plant components. A revolutionary design approach to this high-pressure cell core is needed for an order-of-magnitude capacity scale-up of the individual electrolyzer modules.

Approach

In this project Avãlence is developing an enlarged version of our present design that will have at least 15x the capacity of our present single tubular cell. To achieve this we need to substantially increase the diameter of the individual tubular cell to enable an innovative cell core design – multiple coaxially arranged cylindrical electrodes, nested in a uni-polar configuration – enabling up to 1½ kg/day of production per individual cell. To accomplish this scale-up at 6,500 psi we are partnering with a composite cylinder manufacturer, HyPerComp Engineering Inc (HEI). They will develop a custom designed containment vessel/cathode using their composite technology expertise that will allow us to effectively increase the diameter of the individual electrolysis cell, enable operation at 6,500 psi, and reduce the cell weight and cost relative to conventional metal containment (similar to what is seen today with composite storage tanks). Ninety-six of these high-capacity cells will now produce a single unit (module) with a production capacity of 150 kg/day.

To complete this development process we are proposing to build a quarter-scale pilot plant of this design composed of 24 cells that will replicate the full plant design and operation, but minimize the cost to DOE for this technology demonstration. The pilot plant will be sent to NREL for verification testing over the last three months of this 30-month project. To effectively utilize the pilot plant at the conclusion of the DOE-sponsored portion of this project, we are partnering with the Hydrogen Energy Center of Portland, Maine and MaineOxy, an industrial gas supplier, in Auburn, Maine, who are presently teaming with in an effort to site the pilot plant in Portland for commercial use, supplying high purity oxygen for industrial sales and hydrogen for use in peak shaving and as transportation fuel. They are presently seeking State of Maine funding and local investment to install at least 100 kW of renewable power (wind and/or PV) and perform the necessary site preparation for installation and operation. The final result of the project will be a commercially operating 40 kg/day pilot plant integrated with a wind turbine and/or PV array, and delivering product at 6,500 psi directly to storage cylinders. Operation of this plant and extensive testing of this and earlier development versions throughout the course of the project will thoroughly document the performance and operation of the technology. This combination of an operating pilot plant and substantial performance and operating data will position this technology for commercialization to a waiting market.

Project Milestones

Milestone Description	Completed End of	Status
Preliminary Test Cell Fabricated	Month 5	25% Complete
Preliminary Test Cell Testing Complete (1.000 psi)	Month 7	
Cell Internal Design Frozen	Month 8	
Carbon Wrapped Cell Delivered	Month 9	
Single Cell Testing Complete (6,500 psi)	Month 12	
Efficiency, Manufacturability, and Economics Updated	Month 12	10% Complete
Go/No Go Review	Month 12	
Pilot Plant Design Complete	Month 16	
Pilot Plant Fabrication Complete	Month 22	
Pilot Plant Shakedown Testing Complete	Month 24	
Pilot Plant Performance Testing Complete	Month 27	
NREL Performance Testing Complete	Month 30	

Accomplishments

Work on this project was only begun recently when funding became available. Highlights of the progress are as follows:

- A formal subcontract is being negotiated with HEI.
- The design of the single-cell test apparatus is well underway.
- The design of the 1,000 psi single-cell is well underway.
- Initial discussions with HEI to set the size of the inlet and outlet size.
- Initial testing on the first candidate membrane material to be used in the test was successfully completed.
- Fabrication of the test apparatus was begun.

A drawing of the preliminary design of the 1,000 psi test cell is shown in Figure 1.

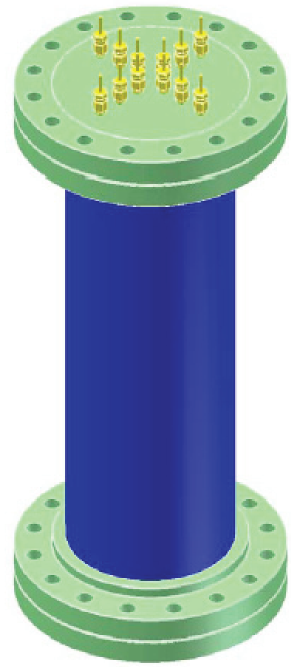

FIGURE 1. Preliminary Design of the 1,000 psi Test Cell

Future Work

Over the next year we will complete the fabrication and testing of the both the 1,000 psi test cell and the 6,500 psi test cell. If funding limitations require we will stretch the work over 15 or 18 months as appropriate.