Solid Oxide Fuel Cells in UUV (Unmanned Undersea Vehicle) Applications

NUWCDIVNPT INVESTIGATORS

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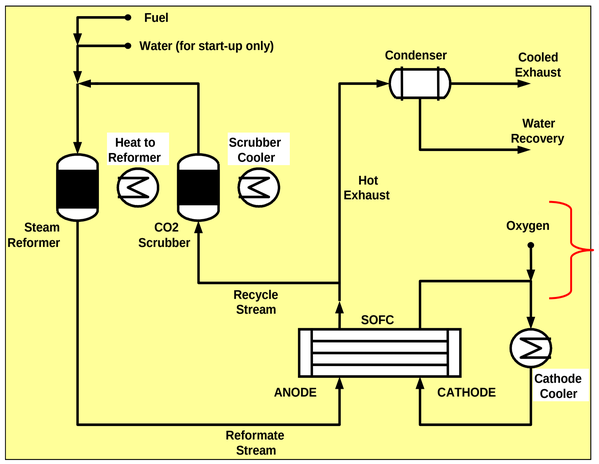
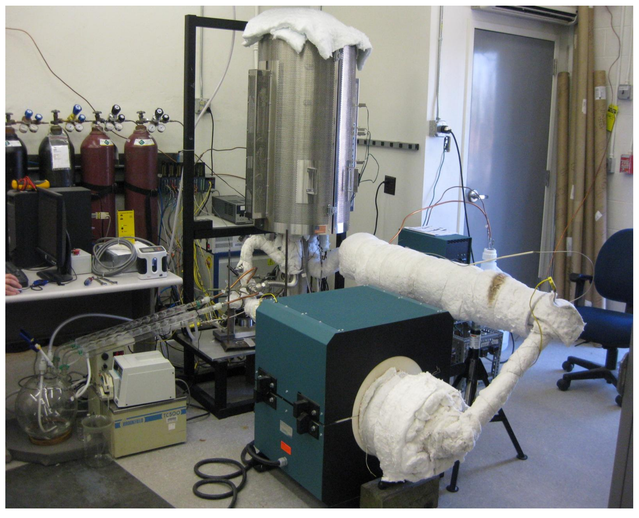
INTRODUCTION

- The U.S. Navy is currently investigating SECA solid oxide fuel cells for the propulsion of Unmanned Undersea Vehicles (UUVs).
- Key goal is to operate a SOFC power source on logistic (military) fuels in an air-independent environment.
- A UUV power source will consist of a SOFC stack(s), fuel processor, carbon dioxide scrubber, balance of plant components and fuel / oxidant storage.



- SOFCs offer several distinct advantages over rechargeable battery technology:
  - potential for achieving specific energy greater than 300 Wh/kg.
  - capable of utilizing energy-dense fuel (extended mission time)
  - "gas and go"--allowing a UUV to be re-launched at short notice.
  - self-sustaining while supplying heat to reforming processes.



Experimental Set-up at NUWCDIVNPT

APPROACH

- Test SECA SOFC Stacks under pure oxygen and reformate
- Evaluate other major system components besides SOFC stacks
- Operate SOFC stacks and components under simulated UUV operating conditions, which is also similar to oxygen-blown coal gasifier plants with hot anode-gas recycle and CO_2 sequestration.

R&D Dynamics

U.S. DOE-sponsored SBIR

Phase II prototype matches 21" UUV design goals

RESULTS

- SOFC stacks from Delphi Corporation and Versa Power Systems have been tested at NUWCDIVNPT's facility

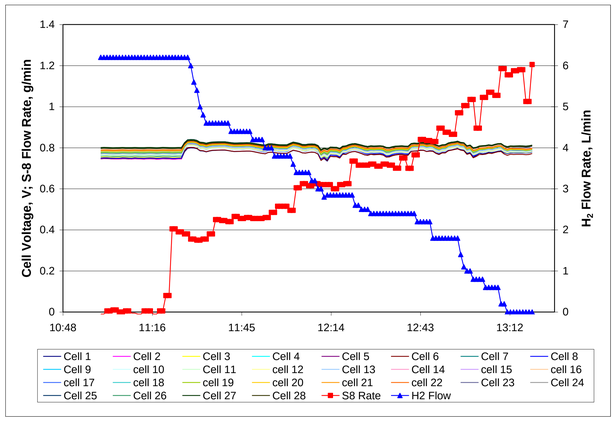
28-cell Versa Power Systems SOFC Stack

Versa Power's standard stack has 121 cm^2 active cell area and requires external compression.

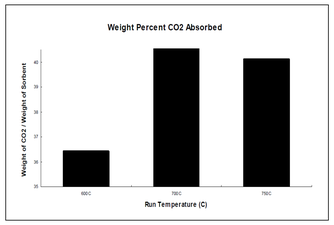
Reactants for system level testing:

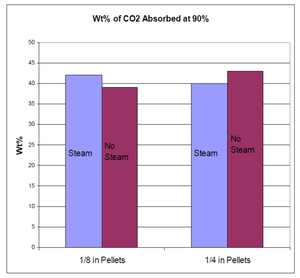
Synthetic S-8 Fuel at anode

Excess air initially used at cathode to eliminate pure oxygen issues. Pure oxygen used in later tests.



Transition from H_2 gas to S-8 fuel
- 22 Amp steady current draw, ~ 500 W
- Stable Cell Voltages, 75% U_{S-8} at system level





TDA Research

CO_2 Sorbent

Removes CO_2 from exhaust gas of SOFC via an active sorbent, calcium oxide-based, which is chemically converted to calcium carbonate at high temperature.

Over 50% mass gain demonstrated

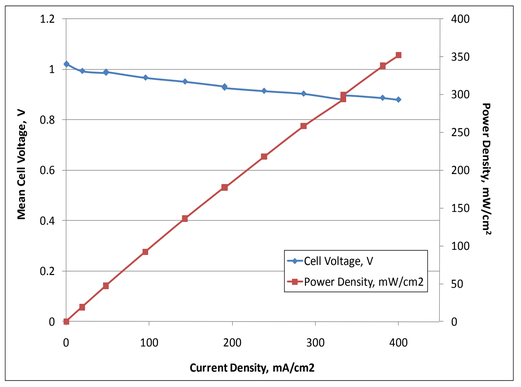
$CaO + CO_2 \rightarrow CaCO_3 + HEAT$ (178 kJ/mol)

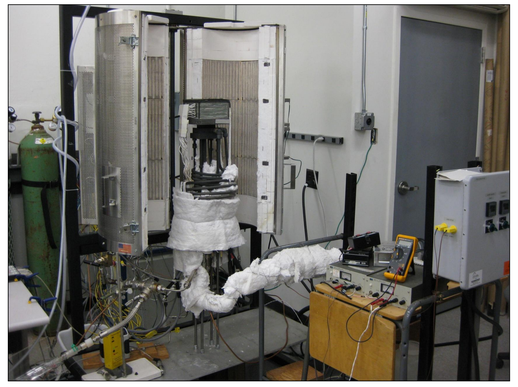
The addition of 80mol% steam to the absorption bed did not significantly alter the performance of the sorbent. Optimum sorbent performance at 700-750 °C.

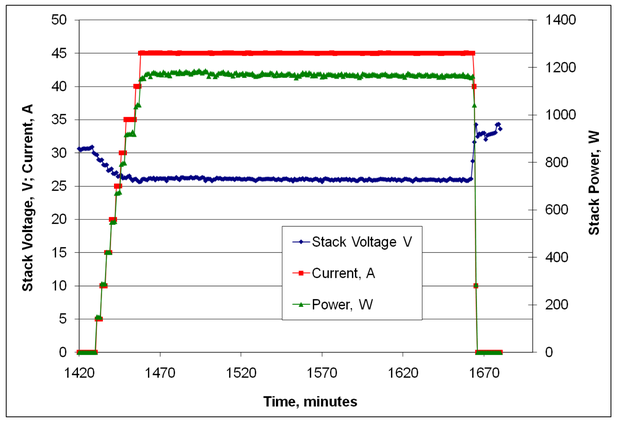
30-cell Delphi Corporation SOFC Stack

The Delphi stack tested was a Gen 3 design with 105 cm^2 cells. This stack design uses welded cassettes and glass-based seal, and it does not require external compression.

IV Plot using high steam level. The anode flow was 20 L/min H_2, 4.4 L/min N_2, and 10 g/min steam (roughly 38%). The cathode flow was 10 L/min pure oxygen. Maximum current density corresponds to 42 Amps, 1090 Watts, and 47% utilization in both fuel and oxidant.







30-cell Delphi Stack operating under simulated UUV reformate gas (20 SLPM H_2, 2.4 SLPM CO_2, 2 SLPM CH_4, 10 g/min steam) and pure oxygen (> 90% utilization). Fuel utilization was ~35% on single-pass basis.

CONCLUSIONS

- SOFC technology has the potential to greatly increase UUV mission time compared with current rechargeable battery technology.
- NUWCDIVNPT is collaborating with DOE & industry to evaluate technologies for undersea power systems. Continued testing in 2010 will evaluate Delphi's fuel processor using several types of fuel and hot anode exhaust from the SOFC.
- Main challenges for UUV application:
  - Oxygen Storage
  - Sorbent Regeneration
  - Start-up
  - Thermal Management