

Preliminary Safety Testing of an Aluminum-Water Electrochemical Reactor

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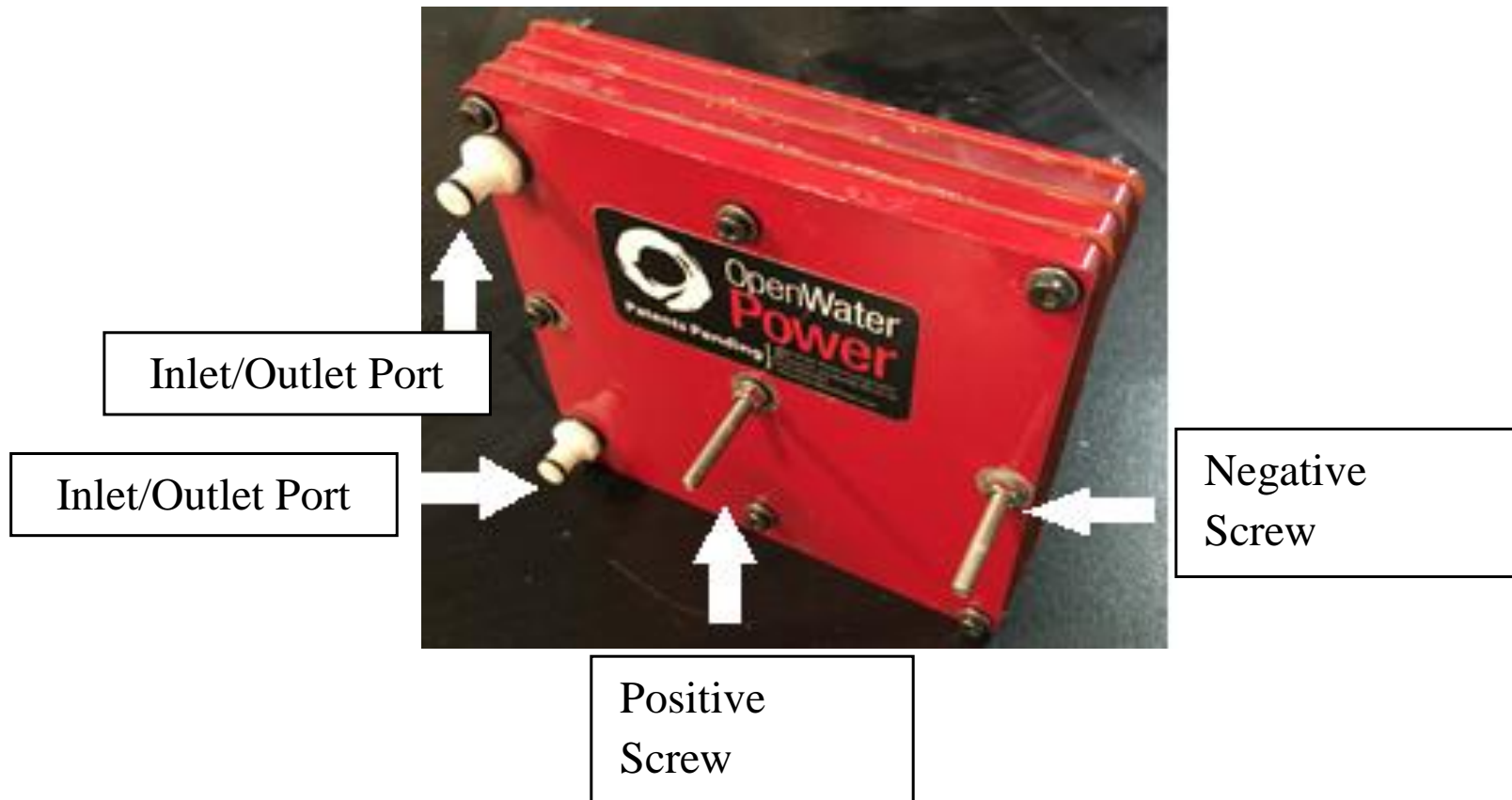
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Background

- Tested electrochemical reactor uses aluminum-alloy fuel, a recirculating KOH electrolyte, and sea water to generate electricity
 - Offers potential energy density benefits over existing technologies
 - Generates H_2 and $Al(OH)_3$ as by-products
- NSWC performed preliminary safety testing on the reactor. Looked at:
 - Transportation and storage environments
 - Fire exposure

Reactor Description

- Manufactured by Open Water Power
- 3 cells in series
- 1.44 kg
- 13cm x 13cm x 3 cm



Test Descriptions

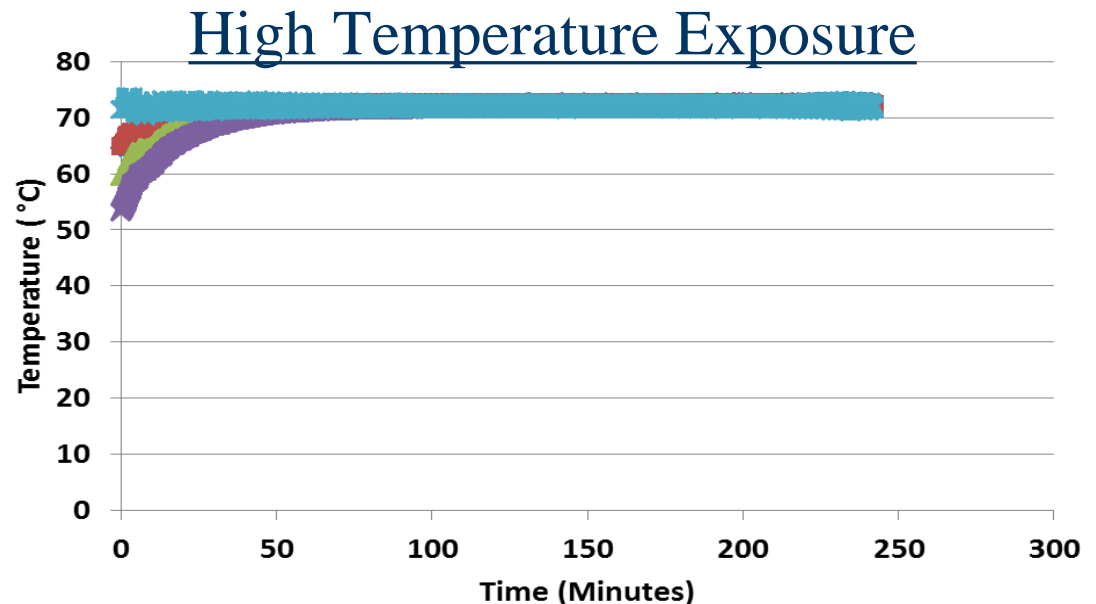
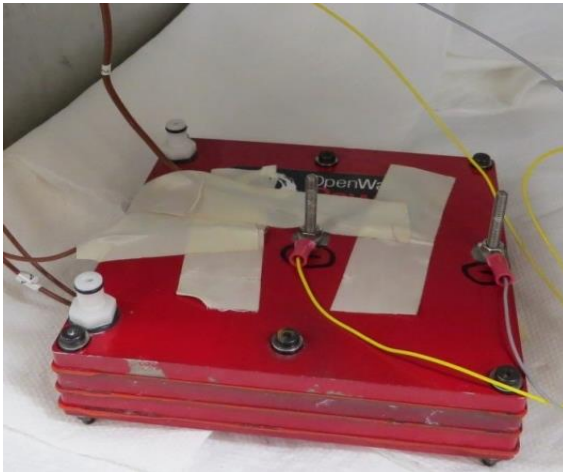
Test	Description
High Temperature*	Stabilized at 71°C then held for 2+ hours
Low Temperature*	Stabilized at -51°C then held for 4+ hours
Low Pressure*	Stabilized at 8.3 psia then then held for 1+ hours
Near Vacuum	Stabilized at lowest pressure feasible given equipment then held for 1+ hours
Activity Verification	Added tap water and measured OCV
Fire Exposure	<ul style="list-style-type: none"> - Exposed to 10 kW fire for 20 minutes - Exposed to 20 kW fire for 20 minutes

*Test specifications from MIL-STD-810G

With the exception of the activity verification test, all tests were performed without added water or electrolyte (inactive state)

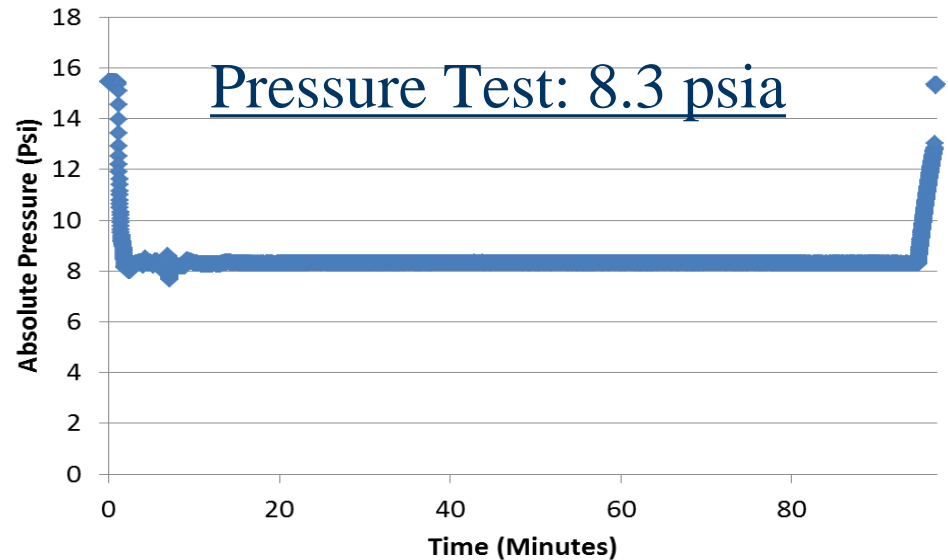
Temperature Testing

- Exposed to 71°C and -51°C in temperature chamber
- Instrumented with thermocouples
- Results: no physical damage, no weight change, and data indicated no unusual activity



Pressure Testing

- Exposed to 8.3 psia to simulate air transport conditions
- Exposed to fractions of a psia to simulate worst case conditions
- Results: no physical damage, no weight change, and data indicated no unusual activity

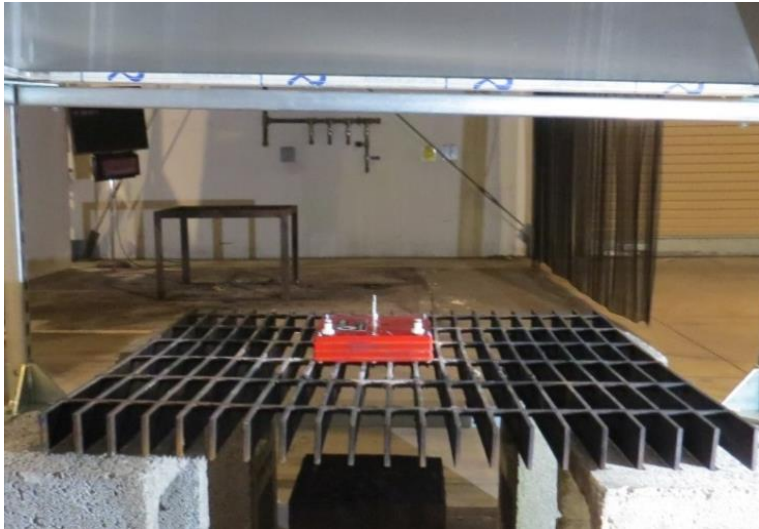


OCV Test

- Added tap water to verify reactor electrochemically active
- Reactor inadvertently shorted for ~20 min
 - No noticeable hazards resulted. Did not measure H₂ release rate, but did not notice off-gassing and there was no weight change.
 - Will perform formal short-circuit test with more active KOH electrolyte in future
- 3 V OCV resulted after short corrected
- OCV orientation dependent
 - May have been result of test setup, e.g. non-recirculating electrolyte
 - Will examine further in future tests

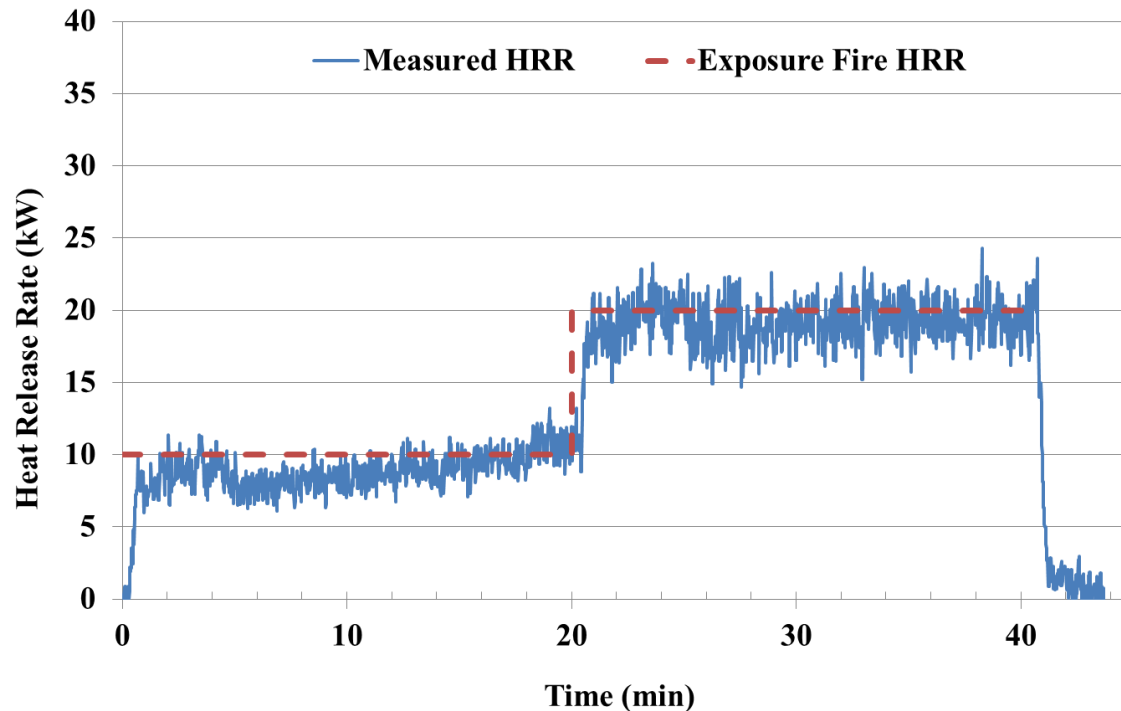
Fire Exposure Test

- Exposed to 10 kW then 20 kW flames for 20 minutes each
- Hood calorimeter used to measure heat release rate (HRR): deviations from 10, 20 kW attributable to reactor
- Concentration of CO, CO₂, O₂, and flammable gases also measured



Fire Exposure Test Results

- Minor flaming observed on inlet/outlet ports, but no measureable heat release beyond that of the exposure fire
- No significant concentrations of combustion gases beyond that attributable to the exposure fire



Reactor

Post-Flammability Test

- Lost ~30 g of weight
 - Mostly intact



Next Steps

- Water exposure test with H₂ measurement
- Short-circuit test with KOH electrolyte and H₂ measurement
- Performance tests to determine energy density and characterize operational behavior

Summary and Conclusions

Test	Description
High Temperature (71°C)*	No hazards observed
Low Temperature (-51°C)*	No hazards observed
Low Pressure (8.3 psia)*	No hazards observed
Near-vacuum (fraction of a psia)	No hazards observed
Activity Verification	Cell shown to be electrochemically active. No hazards observed during inadvertent short, but H ₂ release rate not measured.
Fire Exposure	Minimal burning of non-metallic components. No significant heat release beyond exposure fire.

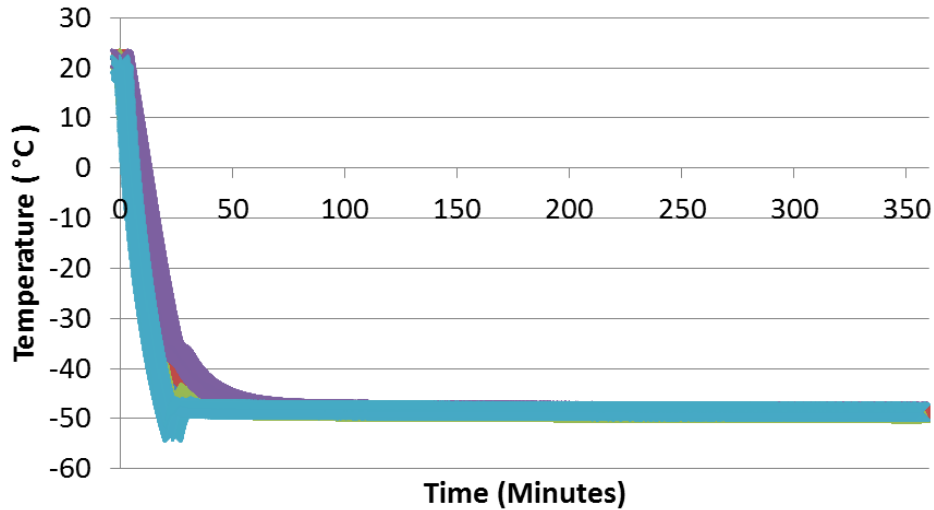
*Test specifications from MIL-STD-810G

Early tests indicate that a reactor – when in an inactive state – does not generate hazards when exposed to extreme storage temperatures, low pressures, or fires

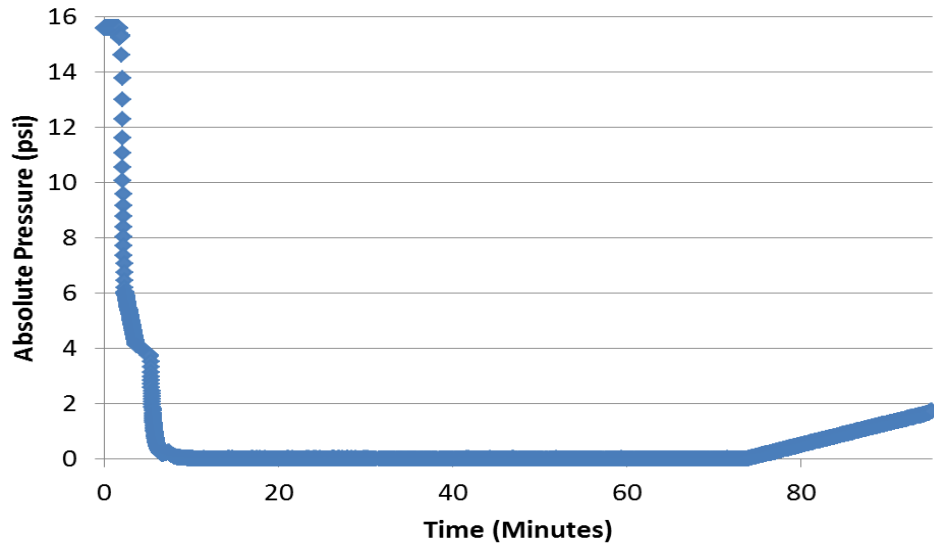
Acknowledgements

- Mike Wardlaw, Office of Naval Research, for funding this effort
- Chris Mealy, NSWCCD Code 616 Fire Protection Group, for supporting the fire exposure test

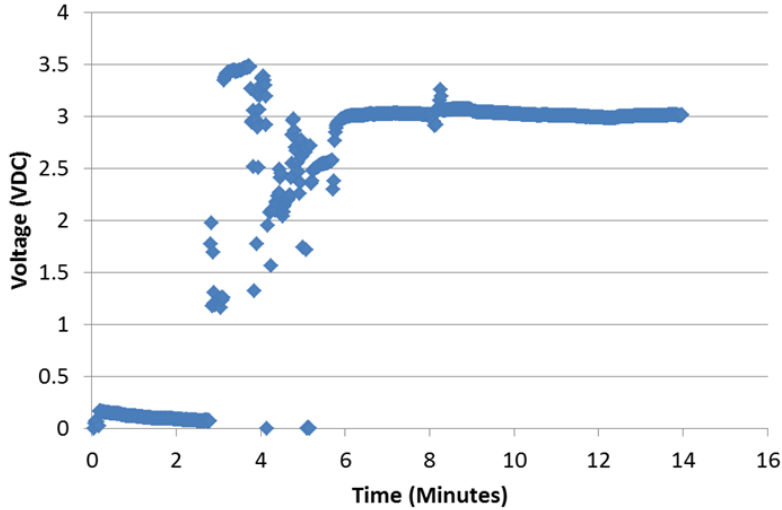
Additional Slides



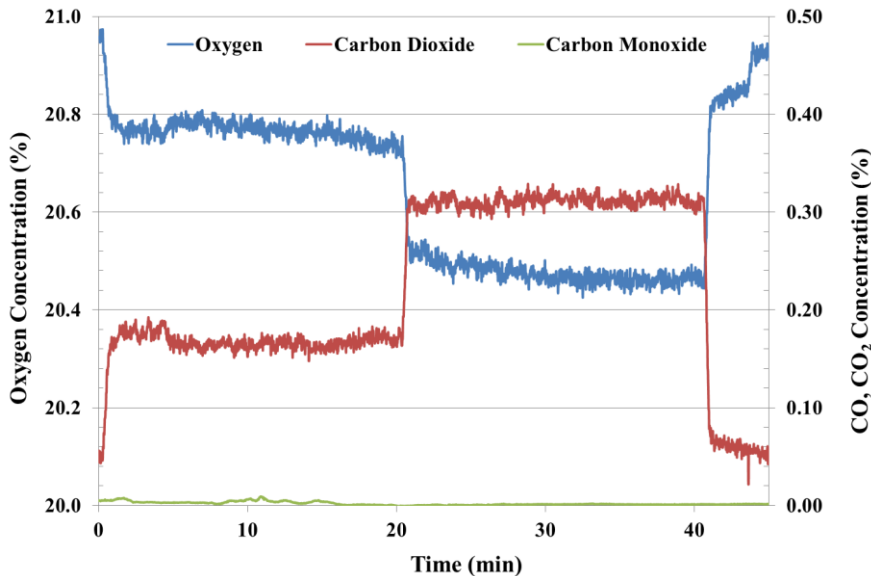
- Cold temperature test data



- Near-vacuum pressure test data



- OCV test data
- Voltage scattered in certain orientations
- To be examined further



- O₂, CO, and CO₂ concentrations from flammability test