Fuel Cell
The fuel and oxidant selected for this system was a sodium borohydride fuel and hydrogen peroxide oxidant. All relevant reactions are as follows:

Anode: \((-1.24 \text{ V})\)
\[
\text{BH}_4^- + 8 \text{OH}^- \rightarrow \text{BO}_2^- + 6 \text{H}_2\text{O} + 8 \text{e}^- 
\]
Cathode: \((1.77 \text{ V})\)
\[
\text{H}_2\text{O}_2 + 2 \text{H}^+ + 2 \text{e}^- \rightarrow 2 \text{H}_2\text{O} 
\]
Overall: \((3.01 \text{ V})\)
\[
\text{BH}_4^- + 8 \text{OH}^- + 4 \text{H}_2\text{O}_2 + 8 \text{H}^+ \rightarrow \text{BO}_2^- + 14 \text{H}_2\text{O} 
\]

**Fuel Cell Design Results**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of cells</td>
<td>16</td>
</tr>
<tr>
<td>Cell operating voltage</td>
<td>1.5 V</td>
</tr>
<tr>
<td>Fuel cell length</td>
<td>29 cm</td>
</tr>
<tr>
<td>Fuel cell volume</td>
<td>23 L</td>
</tr>
<tr>
<td>Cell power output</td>
<td>2 kW</td>
</tr>
<tr>
<td>Cell voltage</td>
<td>24 V</td>
</tr>
<tr>
<td>Energy</td>
<td>~40 kWh</td>
</tr>
</tbody>
</table>

**Experiments**
Creation of a fuel cell with a 97% Au/3% Pt on carbon catalyst.

**Propulsion Model**
- Design based off of US Navy's Mk. 48 Mod. 7 torpedo currently in active duty with all US Navy nuclear attack submarines (SSNs) and nuclear balistic missile submarines (SSBNs).

**UUV Designed Specifications**
- Designed operating depth: 1 km
- Cruise speed: 1 m/s
- Max speed: ~3 m/s
- Dry weight: ~225 kg
- Range (round trip): 70 km

**Experiments & Results**
Performance of second fuel cell using Nafion 117 with higher flow rates. Outperformed thinner Nafion 112, which was more suited for gas reactions.
IPRO Goals

- Investigate potential use of fuel cell to power unmanned underwater vehicle (UUV)
  - Replace the use of conventional battery power
  - Research and design fuel cell power system
    - Design centered on a sodium borohydride (NaBH₄) fuel cell
    - Hydrogen peroxide oxidant (H₂O₂)
- Design a complete submersible package including:
  - Dimensions
  - Control surfaces
  - Material requirements

Fuel Cell Background

- Unmanned Underwater Vehicles (UUV) operate in conditions impossible for manned submarines
  - Naval applications for UUV's include reconnaissance and sabotage
- Current fuel cell technology
  - Hydrogen polymer electrolyte membrane fuel cells most common
  - Research for UUV applications focus on NaBH₄ fuel cell
  - Two to three times more efficient than internal combustion engines
- NaBH₄ fuel cell technology
  - Relatively low environmental impact
  - Liquid reactions produce no gases in cell

Propulsion Background

- Survey of current technology
- Design a vessel around the propulsion system
  - Theoretical design
  - Practical design
- Fully specify and model a practical UUV
  - Modeled in Pro/E

IPRO 349 - The 349er’s

Back row: Chris Chock, Dr. Vijay Ramani, Kevin Abankwa, Kamaldeen Olorunoje, Ethan Baughey, Nic Sansone, Ray Ballard, Brian Olson
Middle row: El Kenig, Dan Miladinovich, Jaya Singh, Sahar Ashrafi, Matt Chaffee, Moses Cho, Jainam Shah, Yukiya Takada
Front row: Chris Wolcott, Suk Hwan Yun, Jenn Guilfoyle, Matt Hagopain, Trang Nguyen, Cheryl Mukai, Marcus Choy

CHE 296

Kevin Abankwa  Brian Olson
Ethan Baughey Olakunle Olorunoje
Matthew Chaffee Nic Sansone
Moses Cho Jaya Singh
Matthew Hagopain Yuekiya Takada
Kamaldeen Olorunoje

CHE 496

Sahar Ashrafi Cheryl Mukai
Ray Ballard Chris Wolcott
Chris Chock Suk Hwan Yun
Jennifer Guilfoyle

IPRO 349

Marcus Choy Daniel Miladinovich
Elezar Kenig Trang Nguyen
Chieh Luo Jainam Shah

IPRO 349: Fuel Cells for Unmanned Underwater Vehicles (UUVs) cooperated with CHE296/496 to create a fuel cell powerplant and complete UUV design intended for US Naval applications.

Spring 2010
Dr. Vijay Ramani, IIT ChBE
http://mypages.iit.edu/~ipro349s10