Center for Commercial Development of Transportation Technologies (CCDoTT)
U.S. Maritime Administration

Seaworthy Systems, Inc.

in conjunction with

MILLENNIUM CELL

Hydrogen On Demand Technology Adapted to and Integrated into Commercial Marine Operation

Hydrogen On Demand Generating System Demonstration – Phase I

CCDoTT FY2001 Program Element 2.16
Subcontract No. DTMA91-97-H0007

Phase I Tasks:

- Literature review
- Evaluate existing commercially viable mobile hydrogen-based technologies
- Conduct safety analyses for shipboard support systems
- Review existing/emerging regulatory codes and requirements for shipboard applications of gaseous fuels
- Develop concept design for shipboard hydrogen-on-demand fuel system and support systems

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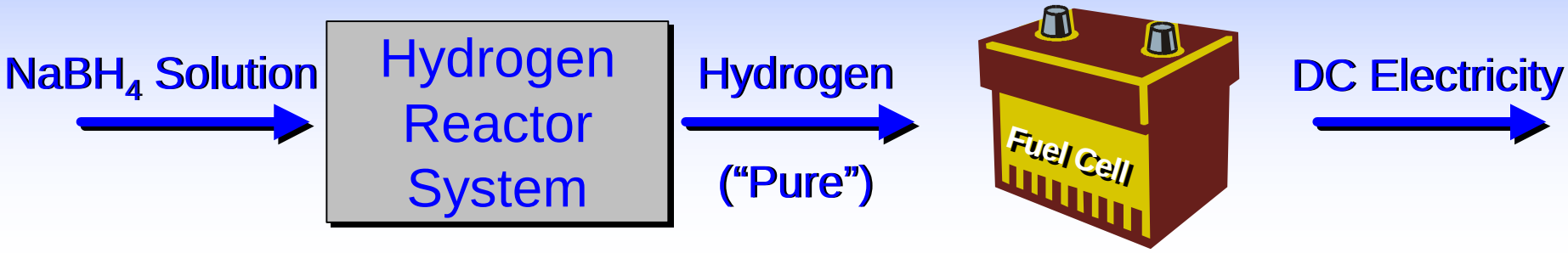
Millennium Cell Hydrogen On Demand™ Fuel System



System Types:

- Compressed hydrogen gas
- Cryogenic liquid hydrogen
- Metal hydride solids
- Water
- Chemical hydride in water (*Hydrogen On Demand*™)

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How Millennium Cell's Hydrogen On Demand™ System Works

On-Board Energy-Releasing System:

$$NaBH_4 + 2\,H_2O \rightarrow NaBO_2 + 4\,H_2 + Heat$$

$NaBH_4$	$2\,H_2O$	$NaBO_2$	$4\,H_2$
20-30% $NaBH_4$ solution, stabilized with ~1-3% NaOH	Proprietary catalyst induces instantaneous hydrogen production	Metaborate (Borax) in aqueous solution with NaOH	Pure humidified H_2 delivered to a fuel cell

- Fuel is a room temperature, ambient pressure liquid
- Generated H2 is pure and at 100% relative humidity
- Borax solution is a warm "ecologically-friendly" water-based solution

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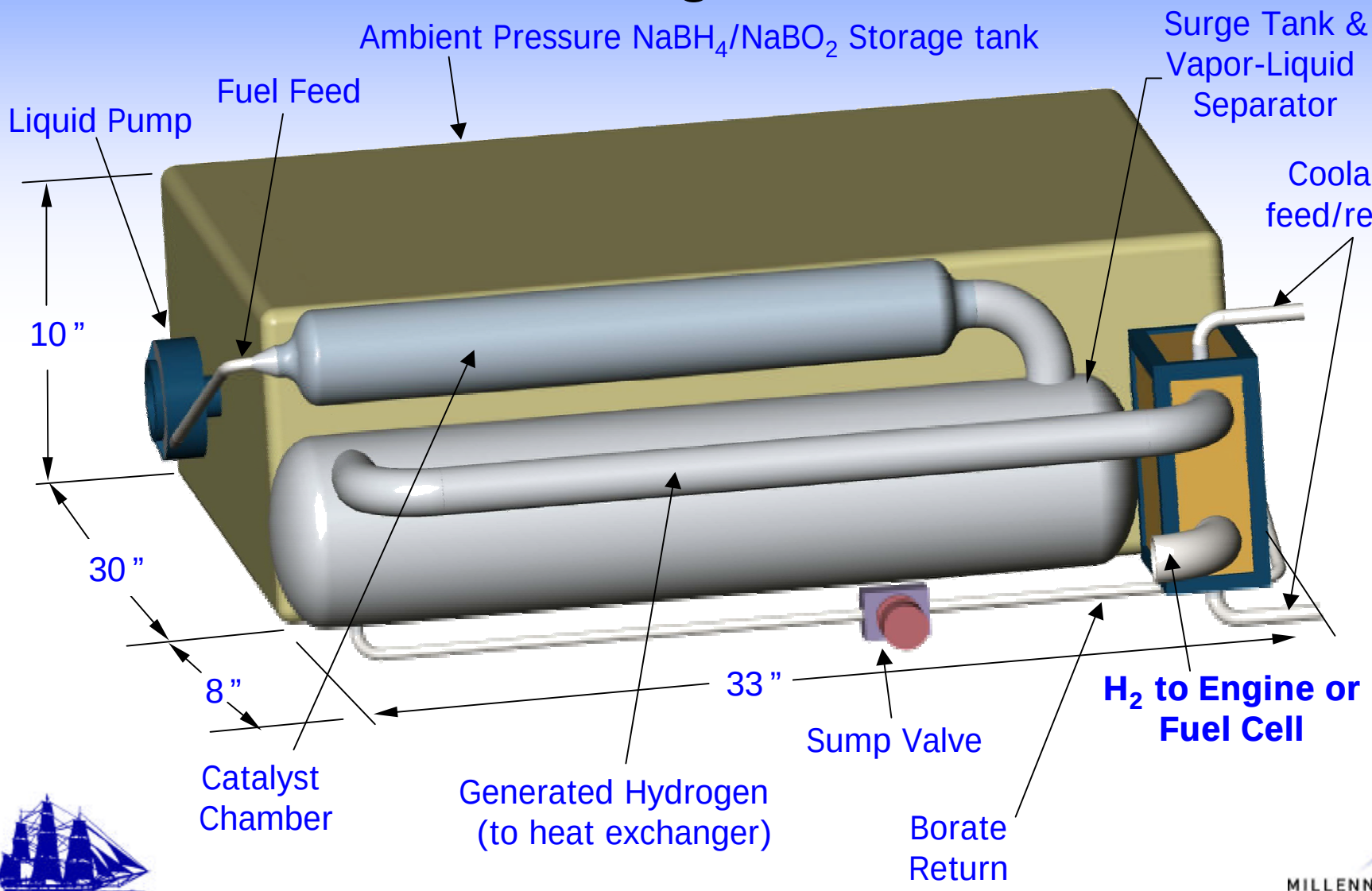
Hydrogen On Demand™ System Configuration



Source: Millennium Cell design

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Hydrogen On Demand™ Summary

- Safe
  - Non-flammable
  - Ambient pressure
- Lowest weight and volume
  - A sodium borohydride-based hydrogen generator offers a solution that is significantly more compact than any other hydrogen fuel alternative.
- Flexible arrangement options
  - This pressure-less liquid enables a wide choice of tank locations and configurations.
- Low complexity
  - Minimal system integration is required to couple a sodium borohydride-based storage solution to a fuel cell or engines.
- Cost competitive
  - Sodium borohydride offers the lowest capital costs relative to other hydrogen fuel options.

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Millennium Cell is Addressing Borohydride Fuel Cost Reduction Through New Process Technology

- Today, $NaBH_4$ is available, but expensive
  - Produced for specialty chemical, not energy, market
  - Available for about $7/dry pound, or $63/kg H_2 at cost
  - Pricing and supply is adequate for next 3 years for Millennium Cell's Distributed Power and Longer-Lasting Battery applications

- New process technology could be cost-competitive with gasoline (preliminary estimates):
  - Large 2,500 tons $NaBh_4$/day plant
  - Services 900,000 fuel cell vehicles
  - Produces fuel equivalent to $2.34/kg H_2
  - Total installed capital cost of under $200 million

Source: Millennium Cell data and Directed Technologies, Inc.

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Thank You for Your Attention

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