

Project Status:

Hawai'i National Marine Renewable Energy Center

Task 2: Test Site Development (2.4) OTEC Heat Exchangers Test Facility

Hawai'i Natural Energy Institute (HNEI)
School of Ocean and Earth Science and Technology (SOEST)
University of Hawai'i (UH)

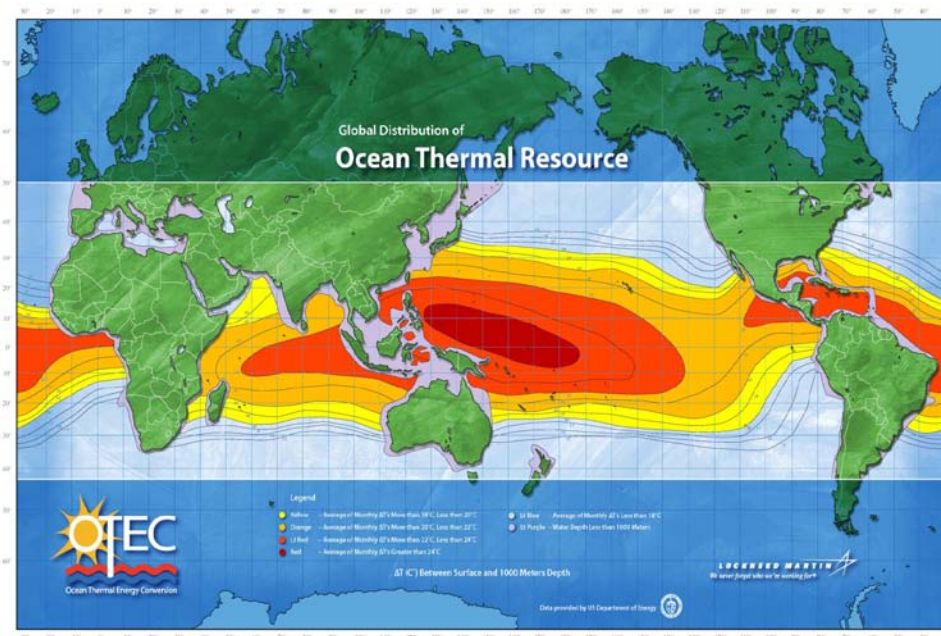
December 8, 2011



Task 2.4

OTEC Heat Exchangers Test Facility

Makai Ocean Engineering, Inc.



Surface vs. Deep Water Temperature Delta

OTEC benefits:

- ✓ Large Renewable Energy Source
- ✓ Base Load (24/7)
 - ✓ No Supplemental Storage Required
- ✓ No Carbon Emissions, clean
- ✓ Not competitive with other vital resources

OTEC Heat Exchanger Test Facility funding:

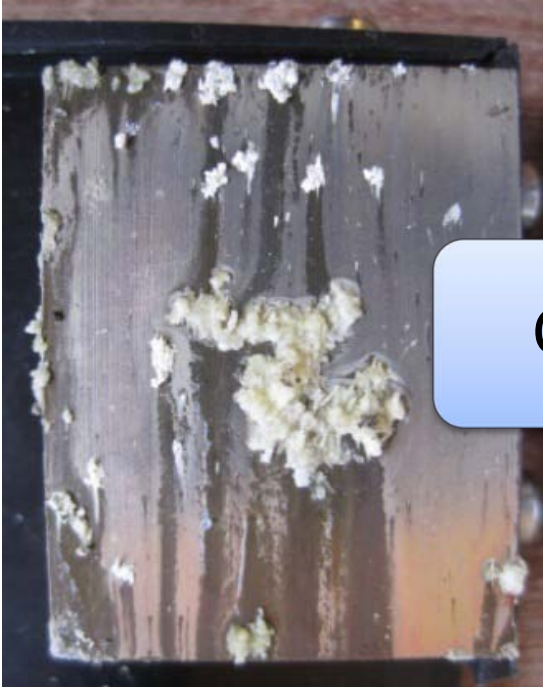
2009: HTDV	\$150,000
ONR	\$1,500,000
NAVFAC	\$1,710,000
2010: ONR	\$1,500,000
2011: ONR	\$1,000,000
2012: ONR	\$2,400,000

Approach to HX Development

Heat
Exchanger
Design



Corrosion



Testing
Facility



HX Performance Testing Facility



- \$2.2M Testing facility to evaluate performance of OTEC HXs
- Built in 2010
- Capacity: 6 heat exchangers
- Maximum SW flows: 8000gpm
- Designed for turbine retrofit enabling OTEC demonstration (100kW scale)
- OTEC system dynamics test (future)

Current HX Development

Evaporator: Brazed Aluminum

Advantage: High performance, acceptable corrosion resistance

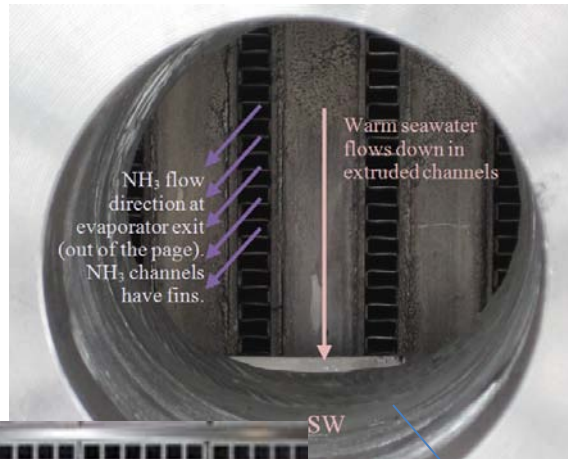
Disadvantage: Relatively high cost

Condenser: Friction Stir-Welded Shell & Tube

Low performance, relatively low cost

Advantage: Very low manufacturing cost, improved corrosion resistance

Ammonia fins



SW

View of ammonia outlet

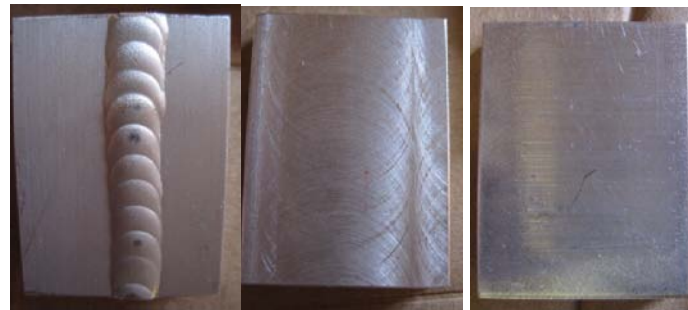
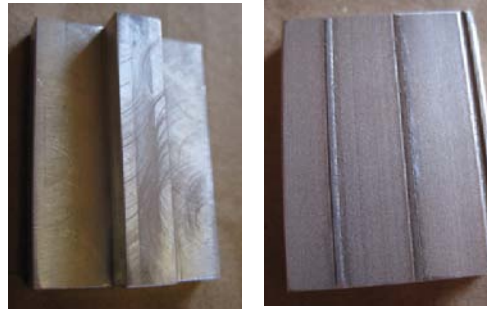
View of SW inlet



View of SW inlet

Corrosion Testing

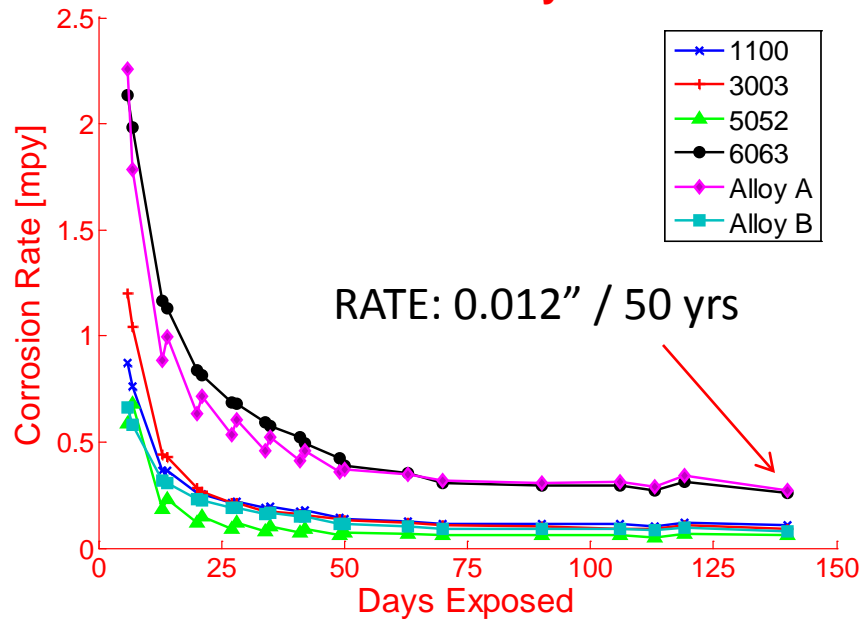
- Performance of alloys and manufacturing processes
- 3 water sources (surface water, 2200', 3000')
- 2000+ corrosion samples



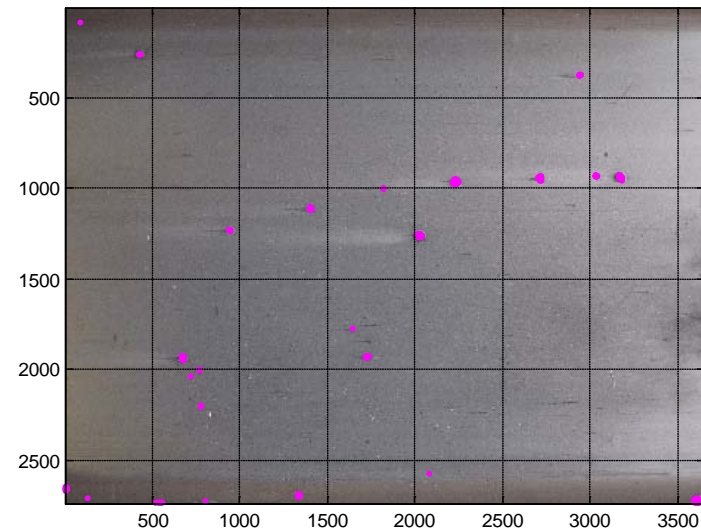
Corrosion Testing

- Uniform Corrosion vs. Pitting Corrosion
- Aluminum HXs would last 200+ years if pits did not develop
- Focus now is pitting measurement and characterization

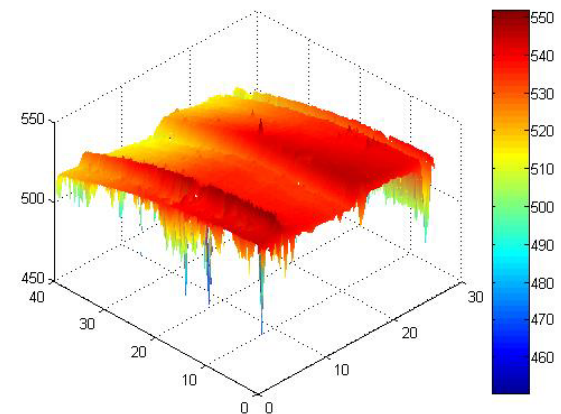
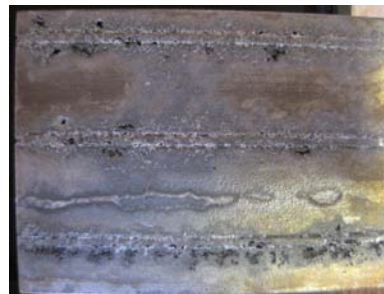
Average Corrosion Rates of Six Aluminum Alloys in WSW



Pit Identification and Characterization



- In situ microscopic imaging of samples (1 micron/pixel)
- Pit accumulation over time (# of pits per area)
- Pit growth rates (diameter and depth over time)



In-situ ultrasonic scan of samples for pit growth monitoring

Future OTEC HX development

- Install and test next HX (Lockheed Martin) ONR FUNDED
 - Graphite Foam technology
- Design, build and test 3 new OTEC heat exchangers ONR FUNDED
- Expand corrosion testing ONR FUNDED
 - Performance of coatings
 - Pitting treatments
- Pitting characterization HINMREC FUNDED
 - Pitting growth monitoring
- Alternate biofouling treatments ONR FUNDED
 - Ozone
 - Iodine bubbles
- Turbine purchase, installation, shakedown - \$1.7M unfunded -
- Power Cycle / Dynamics Testing - \$2.2M unfunded -