OTEC Power Cycles and Auxiliary Uses

C.B. Panchal

E^{3}Tec Service, LLC

Phone: 443-812-5930

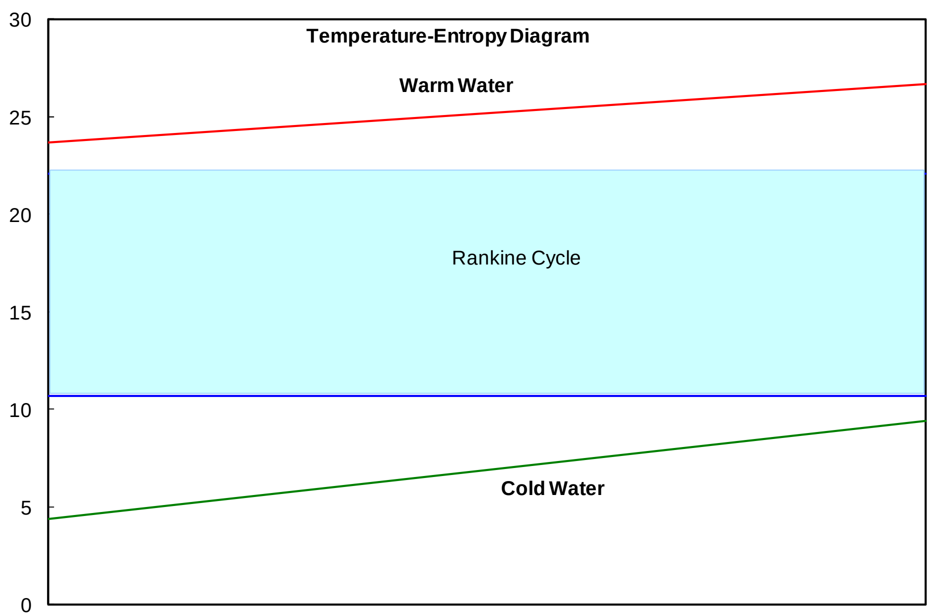
cpanchal@msn.com

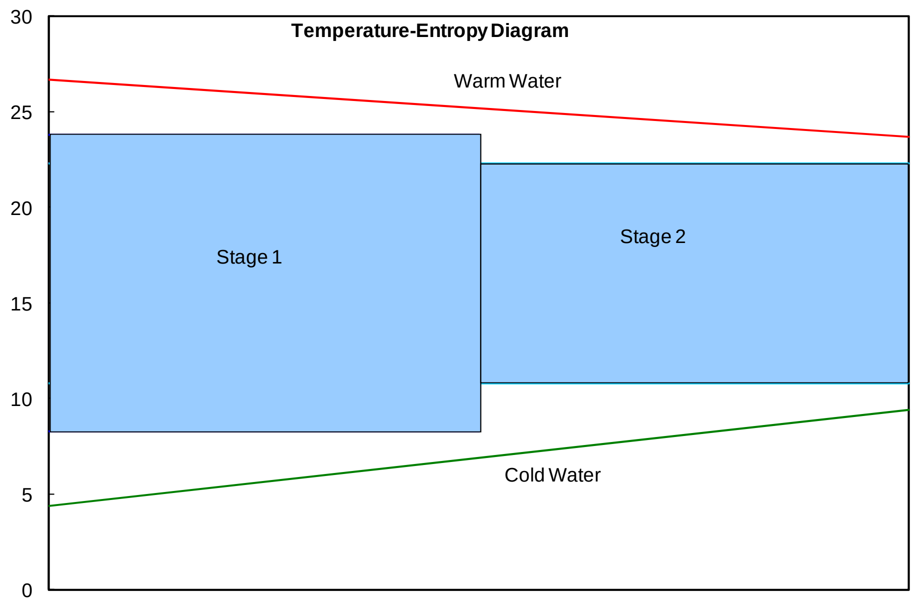
OTEC Power Cycles

- **Closed Cycle: leading power cycle; ammonia or hydrocarbon working fluid; single stage or multi-stage**
- **Open Cycle: originally pursued by Westinghouse and 210 kW Prototype system tested at NELHA, Hawaii**
- **Hybrid Cycle for co-production of power and desalinated water: pursued by Westinghouse (large scale plants) and Argonne National Lab (small land-based plants)**
- **Ammonia-Water Absorption Power Cycle: Pursued for Geothermal power and being considered for OTEC**
- **Mist-lift Cycle: Prototype unit tested; no significant development work pursed**
- **Salinity-Gradient Cycle: Concept developed**

Rankine-Cycle – Single vs Multi-Stage Cycle

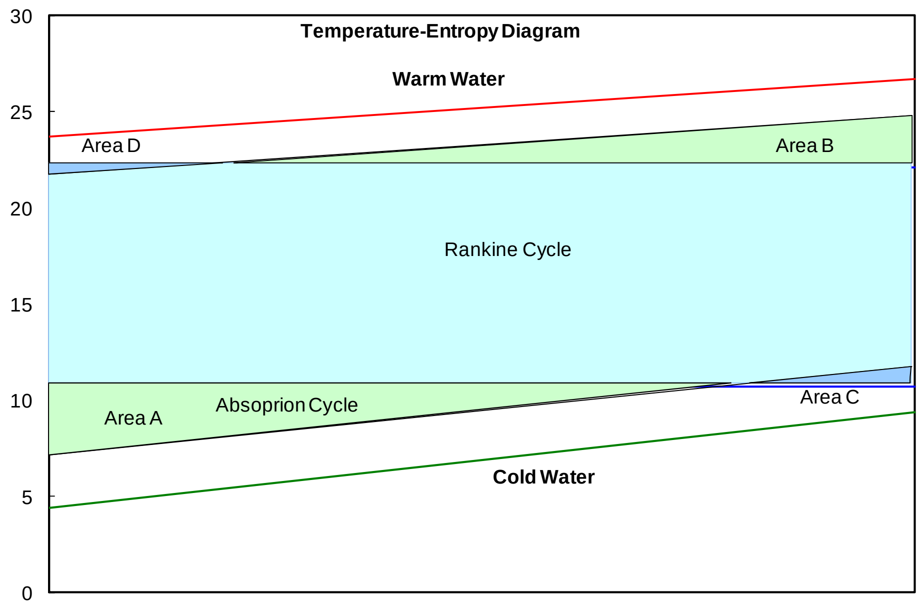
Effective utilization of seawater temperature difference without high costs of heat exchangers is key to the overall economics of OTEC plants

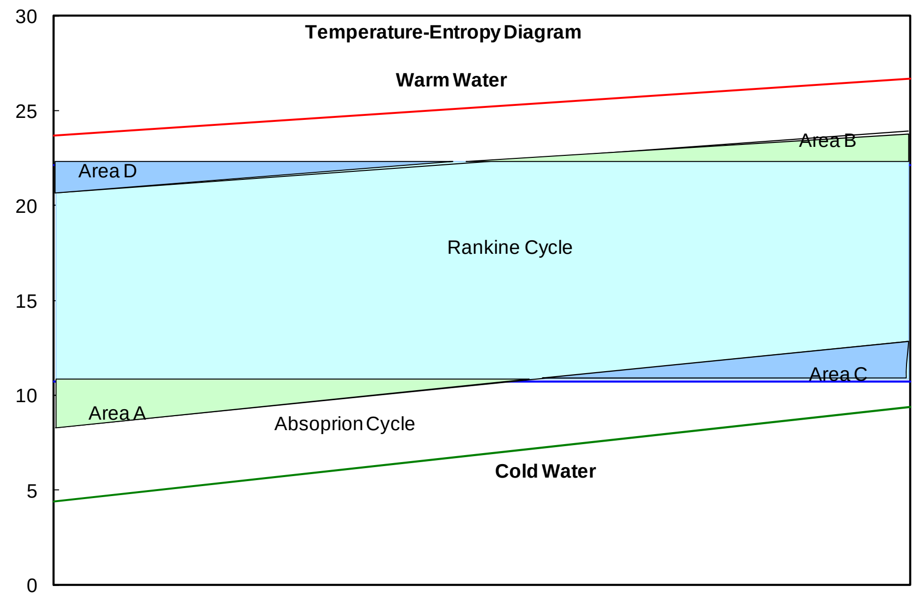




Ammonia-Water Absorption Power Cycle

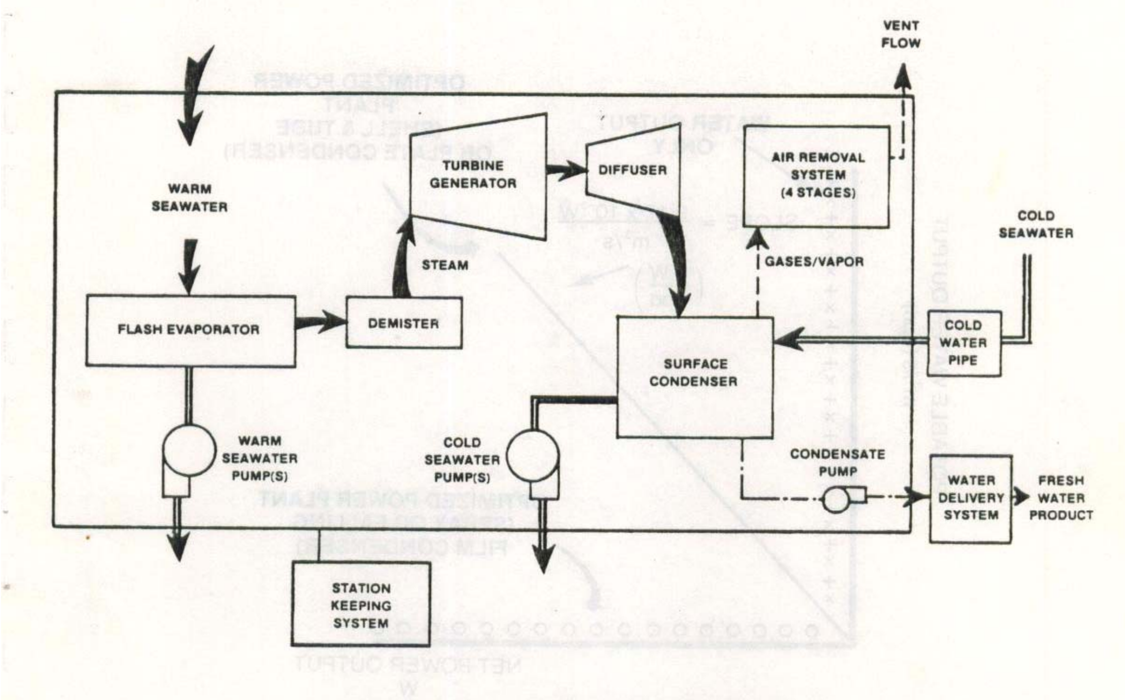
Heat/Mass transfer resistances that would produce non-equilibrium conditions limit the thermodynamic advantages of ammonia-water absorption power cycle





Open Cycle

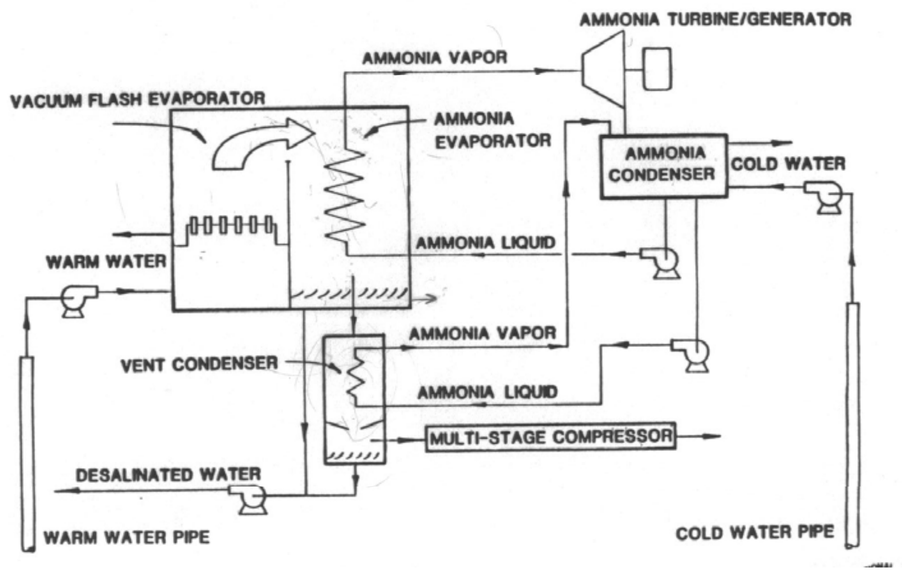
Large scale low-pressure turbine is a key component to be developed for commercial viability of OC-OTEC plants

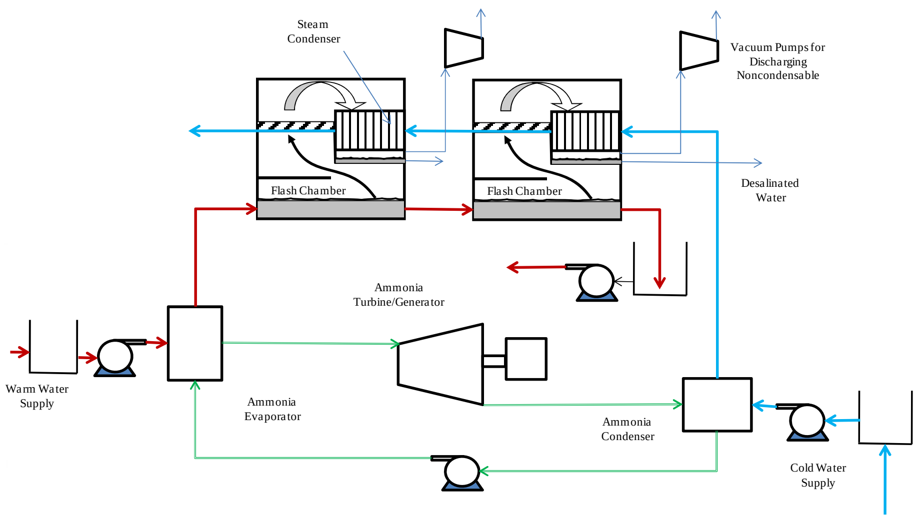


OPEN CYCLE SCHEMATIC DIAGRAM

Hybrid Cycles for Coproduction of Power and Desalinated Water

- **Integrated Hybrid Cycle**
- **Combined (Parallel or in-Series) Hybrid Cycle**

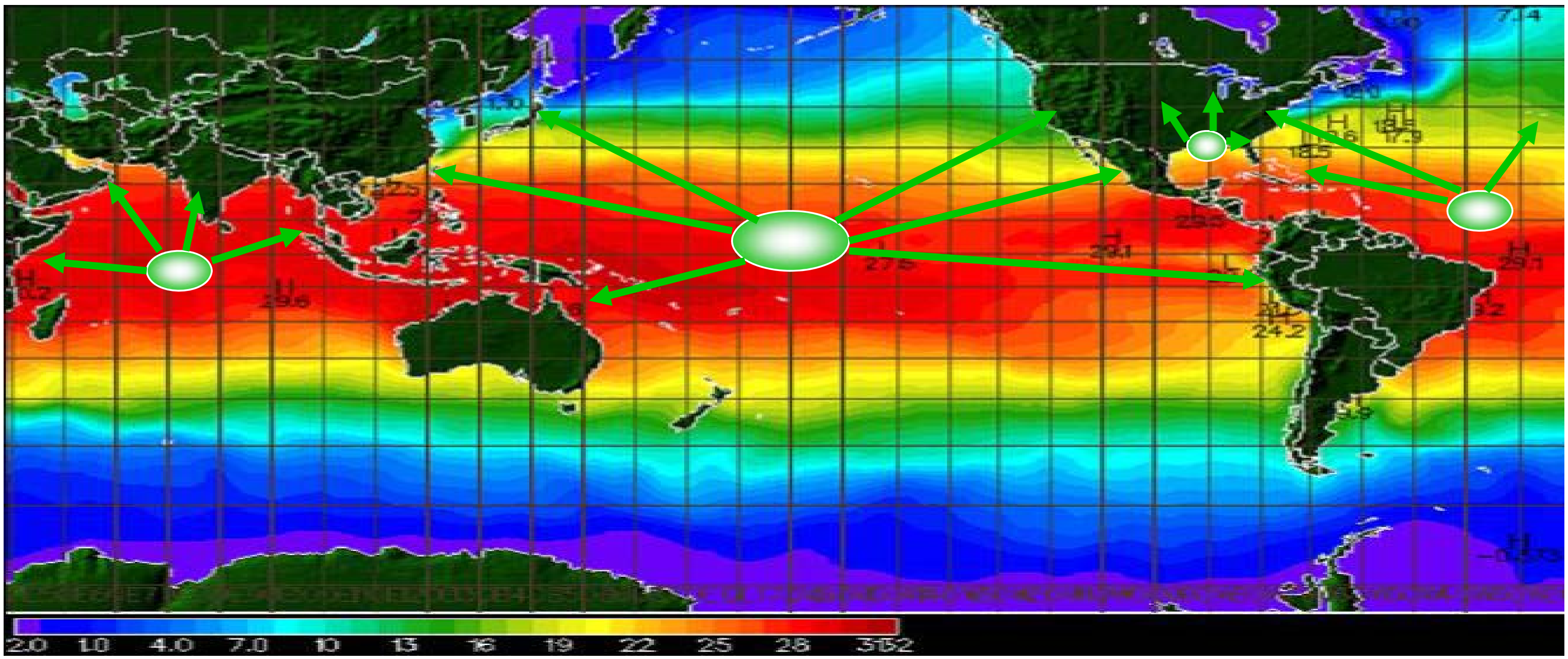




On-Board Reverse Osmosis (RO) is an option for <u>at-sea</u> production of desalinated water

OTEC Plantships for Ammonia Production

- **Ammonia is being considered as the hydrogen carrier for renewable energy sources – wind, remote PV, and OTEC**
- **Global impact of OTEC Plantships – Four Strategic Regions**



Other Auxiliary Uses and Products

- Cold-water can be used for air-conditioning at selected sites
- Mariculture seems attractive; however, limited to land-based plants with additional requirements of seawater quality for downstream use of seawater for mariculture
- Micro-Algae is being pursued for small OTEC plants for favorable island sites

Technology Status

- 1st Generation of Commercial OTEC plants will most likely be designed based on closed cycle with ammonia as the working fluid
- Hybrid cycle would be considered for sites with critical water requirements
- Towards the end of federal funding in 1980s, aluminum was qualified for OTEC heat exchangers and biofouling became manageable; however, further development work could not be continued to develop OTEC-optimized modular aluminum heat exchangers
- Multi-stage Rankine cycle requires the development of modular high-performance heat exchangers that can be easily integrated with out significant engineering

Technology Status

- Ammonia-water absorption cycles have potentials in 2nd or 3rd generation of OTEC plants with the development of high-performance of heat/mass transfer exchangers
- There are critical technical issues to demonstrate the viability of the mist-lift cycle for large OTEC plants due to the uncertainty of the two-phase flow in large riser pipe
- Haber-Bosch is commercial ammonia synthesis process hydrocarbon as feedstock
- Innovative solid-state ammonia synthesis process has been proposed with significantly improved energy efficiency
- Technical and economic viability of OTEC micro-algae based fuel need to be evaluated

Path Forward

Five-Step Commercialization Goals

1. Global displacement of petroleum-based fuels (diesel and fuel oil) for power generation specifically in the island market
2. At-sea production of desalinated water for regions of critical water shortages
3. Displacement of carbon-based production of fertilizer ammonia
4. Hydrogen supply to allow economic processing of heavy crude oils and upgrading oil sands
5. Ammonia-fuel-based distributed energy to displace natural-gas for power generation