NOAA OTEC Technology workshop
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Plenary session 5-minute overviews of OTEC major sub-systems

Cold Water Pipe

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OTEC's biggest challenge: A very large single* Cold Water Pipe is required

The CWP for a full-scale 100 MW OTEC plant is 10m / 33 ft in diameter

*Multiple CWP's require unacceptable pumping power

http://2.bp.blogspot.com/_7tB79IR_qrQ/SCVh6hwIVBI/AAAAAAAADn0/l5plCrhYsAk/s400/empireStateBuilding.jpg

The CWP must meet a number of requirements

Quantifiable technical drivers:	Anticipated quantitative loading	*Dominant driver?*	Met in LM design?	Basis
Buckling from net external pressure	7.5 psi suction inside CWP at top	**Yes**	Yes	FEA
Bending fatigue from platform motions, including knockdown for long-term seawater immersion	Approx. +/- 4 degrees of pitch or roll, plus surge and sway motions	**Yes**	Yes	Prelim. HARP analysis (10 MW plant) + prelim. test data on fatigue after high-pressure seawater conditioning to saturation
Buckling from platform motions	Same as preceding	No	Yes	FEA
Fatigue from Vortex-Induced Vibration (VIV)	Sheared current profile, approx. 4 fps surface velocity	No	Yes	Several analyses indicate no excitation of CWP in sheared currents
Tensile failure from clump weight and streaming current	CWP + clump weight; current profile	No	Yes	Bending and tension strain calculations
Core collapse from high pressure at 1000m depth	1500 psi	**Yes**	Yes	Venting of hollow core eliminates net pressure on core
Wet weight must be positive but not excessive	CWP & clump weight	**Yes**	Yes	CWP wet density is same as fiberglass/vinyl ester laminate
Corrosion	30-year immersion in seawater at depths to 1000m	**Yes**	Yes	Industry experience with fiberglass/ vinyl ester composites
Also:				
Behavior in service must be very reliable	CWP is single point of failure for OTEC plant	**Yes**	Yes	One-piece CWP eliminates maintenance / repair / failure of joints
Deployment must be low-risk	Very large consideration - Previous OTEC failures have been dominated by CWP deployment	**Yes**	Yes	Fabrication directly from the platform eliminates large risks associated with transport, assembly, upending, etc.
Cost must fit within OTEC plant budget profile	Electricity cost <= $0.25/kwh for 100 MW OTEC plant in Hawaii	**Yes**	Yes	Minimum-cost design through optimization. Materials costs from supplier quotes; recurring fabrication costs from large wind turbine blade data

To meet these requirements, a number of top-level choices must first be made

- Material (fiberglass? steel? HDPE? membrane?.....)
- Architecture (monolithic? sandwich?)
- If a sandwich, what type of core (foam? honeycomb? balsa? hollow laminate?)
- One-piece? Assembled from separately fabricated lengths using mechanical or bonded joints?
- Fabrication method and location (on-shore? from the platform?)
- Deployment method
- Rigidly attached to platform? Gimbaled?

Issues and path forward

There is no available “off the shelf” CWP solution that meets all of the requirements at the required size scale.

Relevant existing technology ingredients are available (some developed in recent decades), but they must be synthesized into a new CWP solution.

Careful judgment and quantitative optimization are necessary to choose the best ingredients and integrate them into the new solution.

Thorough development, prove-out, and scale-up are necessary to retire the risks.

Within Lockheed Martin’s OTEC program, the ingredients for our baseline CWP have been chosen, the selected fabrication process has been proven out in the laboratory, and scale-up validation is now underway with the help of DoE funding (under their AWPP program) and US Navy funding (under NavFac’s OTEC program).

These activities (now ongoing) will bring the OTEC CWP to a state of technological readiness for commercial deployment.