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JIP Proposal for FEF at BV Paris, 28th June 2023

“Design and Model Testing of Large Diameter Deep Cold Seawater Intake Pipes for FPSOs, FLNGs and OTEC”

Martin G. Brown, Consultant Naval Architect,

Ocean Energy Systems Limited (OESL), Aberdeen.

Prof. Joel Sena Sales Jr.

Federal University of Rio de Janeiro (UFRJ) - Brazil

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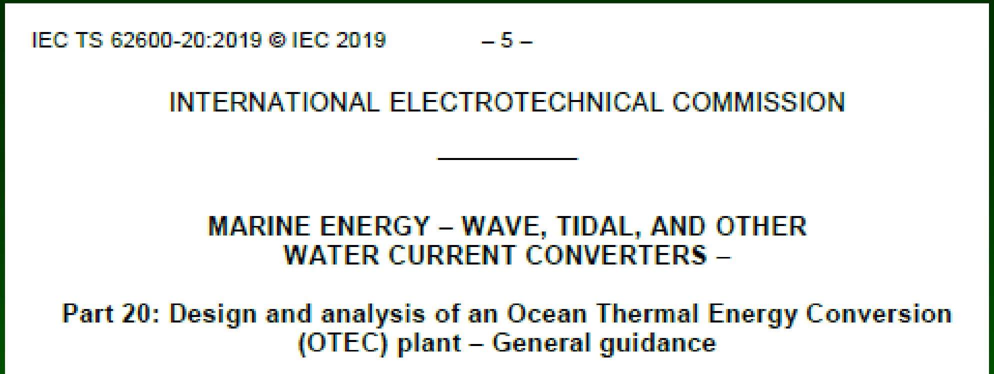
Backgrounds



INTERNATIONAL ELECTROTECHNICAL COMMISSION

MARINE ENERGY – WAVE, TIDAL, AND OTHER WATER CURRENT CONVERTERS –

Part 20: Design and analysis of an Ocean Thermal Energy Conversion (OTEC) plant – General guidance

- **Martin Brown, Naval Architect (OESL)**
- Project manager Noble Denton FPS Mooring Integrity JIPs
- Vice Chairman – Europe and America, Ocean Thermal Energy Association (OTEA)
- IEC OTEC Standard Convenor

- **Prof. Joel Sena Sales Jr.**
- Prof. Hydrodynamics, Naval Architecture & Ocean Engineering, COPPE/Federal Uni of Rio de Janeiro
- 2015-2018 Manager - Lab of Waves & Currents, LOC/COPPE/UFRJ
- 2010-2015 Offshore Research Manager – LabOceano Ocean Basin
- 2003-2010 Project Manager - LabOceano including Lockheed Martin OTEC Model Tests

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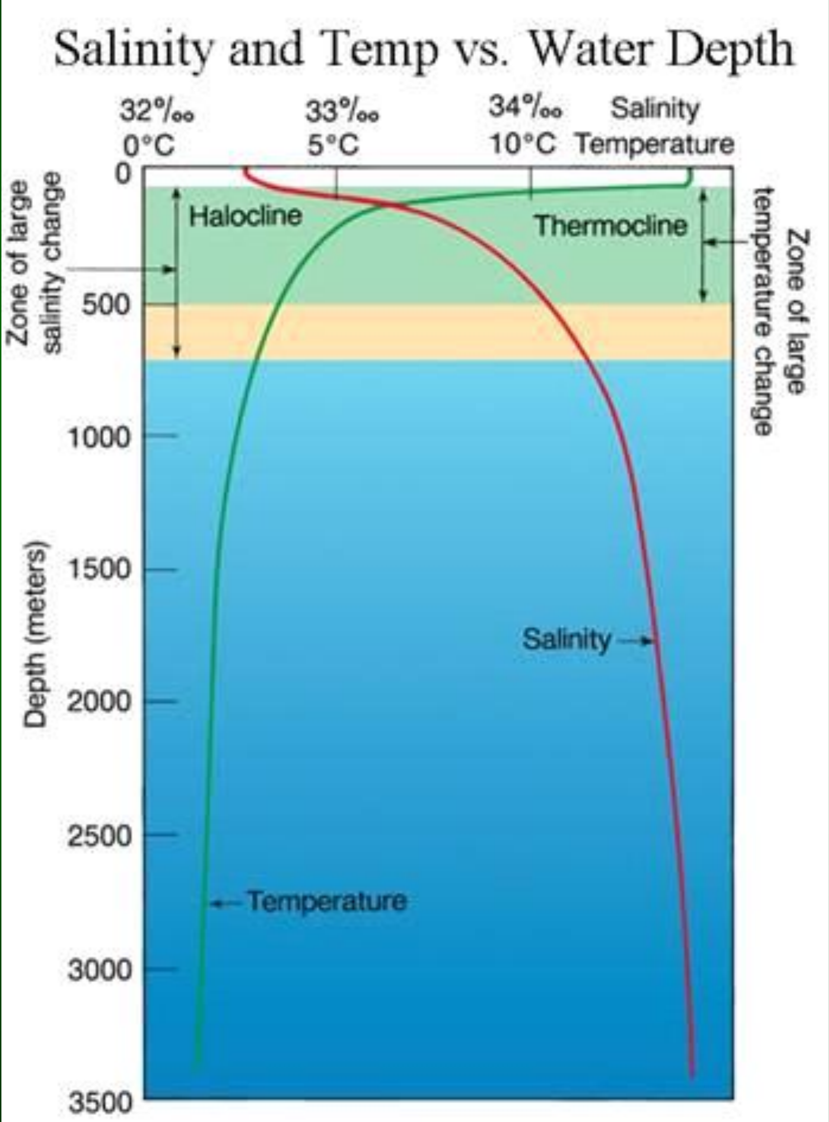
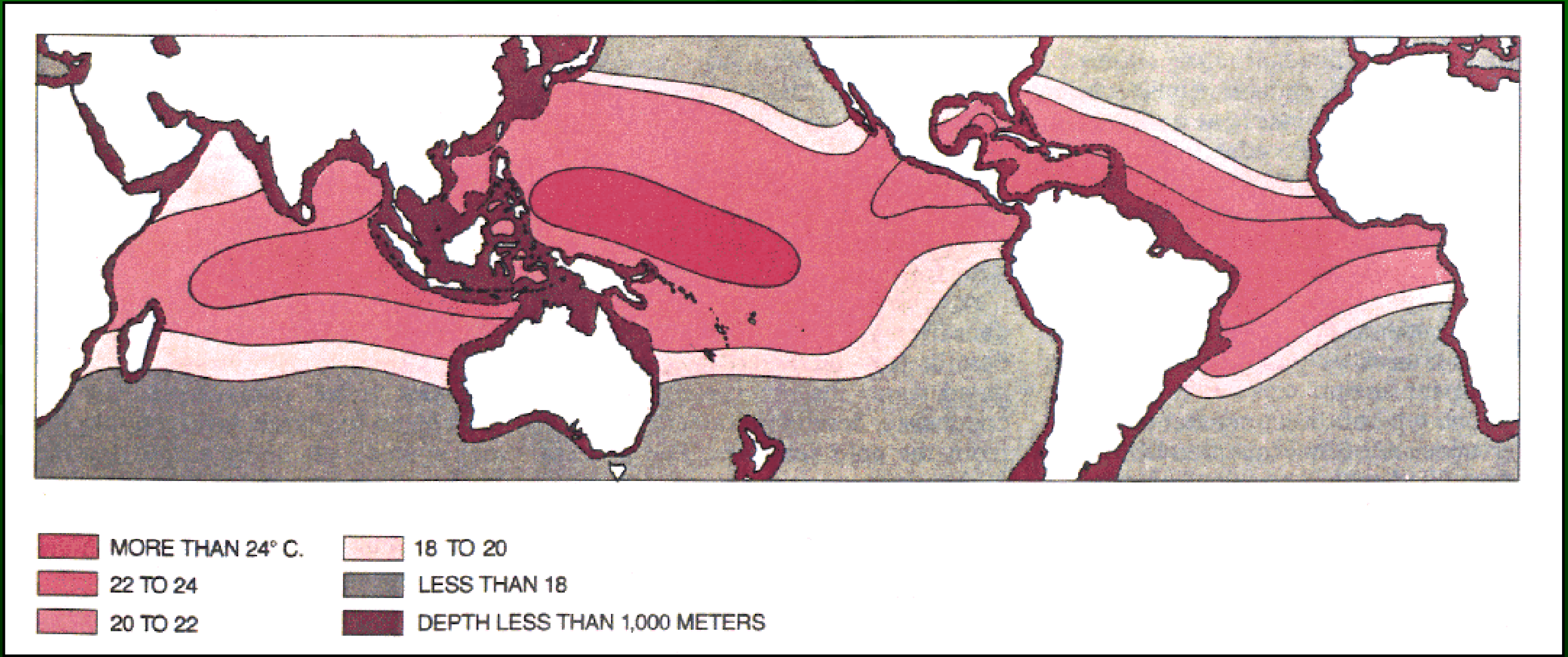
Cold Water Source



Tropical ocean surface temperature > 28ºC at 700 to 1,000m about 4ºC all year round due to the thermocline

Deep water is relatively pure and free of pathogens so biofouling of process equipment will be less



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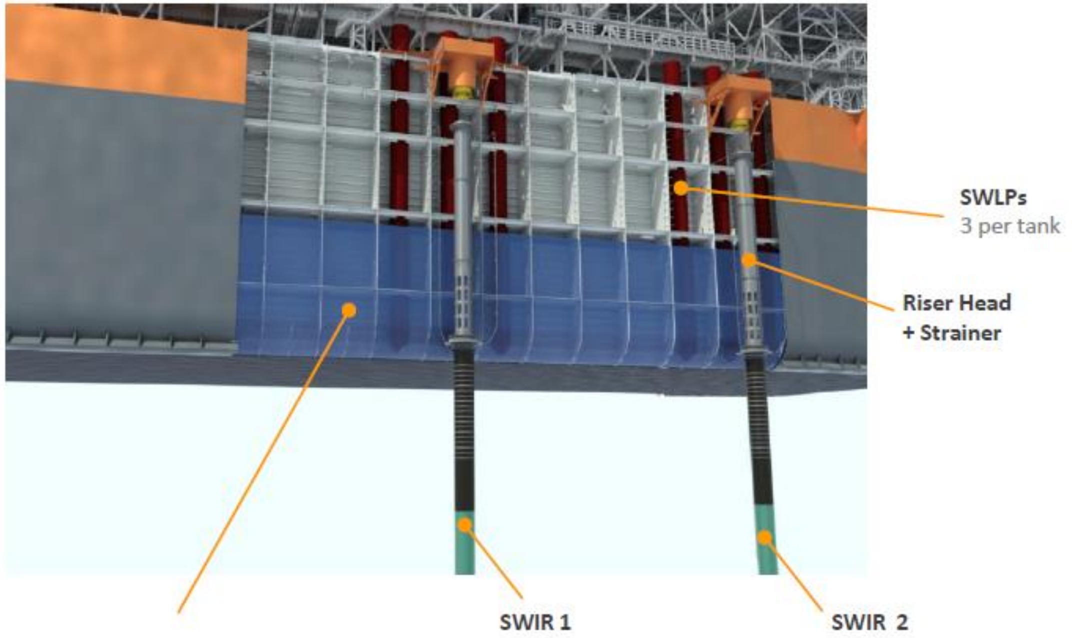
Redundancy needed plus only ≈1m dia, 700m Intake depth

Eli Gomes, MSc PhD
Principal Topsides Engineer
Shell Brazil

Seawater intake riser



QUICK SUMMARY:

- **Communicating Vessels Concept**
- Captures water at ~700m water depth
- Water at 8°C -> CM and SW systems mainly impacted
- Water flow rate is up to 15500m^3/h
- Systems are installed in New Builds / During Conversion
- 2 SWIRs per FPSO
- Systems are **100% redundant**
- **SWLPs are located inside the tank** and captures water from inside of the tank
- 3 SWLPs per tank -> Total 6 SWLPs on the FPSO
- Water Ballast tanks will be converted to **Sump tanks.** Sump tanks are necessary to act as a "buffer" for the SWLPs
- System is located at Starboard (Opposite from Riser Balcony)

Major De-Carbonisation Benefits

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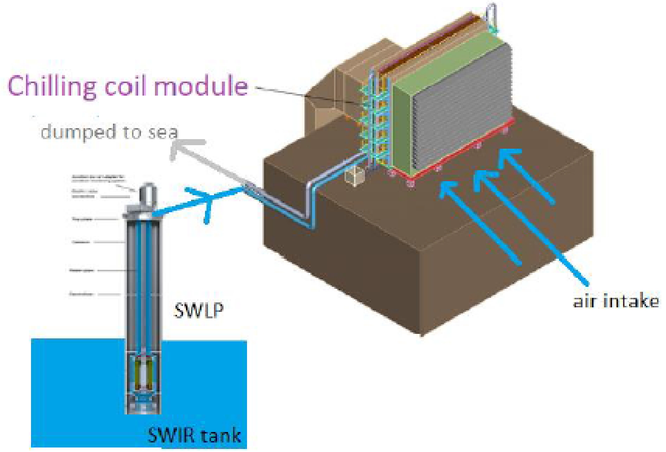
Guilherme Pinto, SBM Offshore

Topsides Optimization

OVERALL TOPSIDE IMPACT EVALUATION

SBM OFFSHORE

Lower Seawater Supply Temperature	Lower SW Lift Pumps flowrate and power. Improved consumers efficiencies. Lower heat transfer areas.
Lower Cooling Medium Supply Temperature	Lower CM Pumps flowrate and power. Lower heat transfer areas.
Heat Ingress and Insulation for SW and CM Piping	SW and CM piping may require insulation.
GTGs Inlet Air Cooling	Increased GTGs performance. Increased GTG power output. Reduced Fuel Gas consumption. Reduced CO_2 emissions.
Gas Cooling in Gas Processing Plant	Reduced compressors power requirement. Increase in condensate recycle to oil system.
Gas Cooling for Dehydration	Reduction of Dehydration Package.
Gas Cooling for Hydrocarbon Dew pointing	Reduction or removal of Mechanical Refrigeration Unit.
Increased Oil Recovery	Increase in oil flow to cargo tanks.
Improved Filtration for Water Injection	Reduced cleaning frequency for basket filters and back-washable filters. Reduced cartridges exchange for cartridge filters.
Reduced SRP Membranes Clean In Place and Changeout Frequency	Increased SRP uptime. Increased SRP membranes life-span
Deaeration Vessel	Less dissolved O_2 in seawater. Colder temperature requires more vacuum



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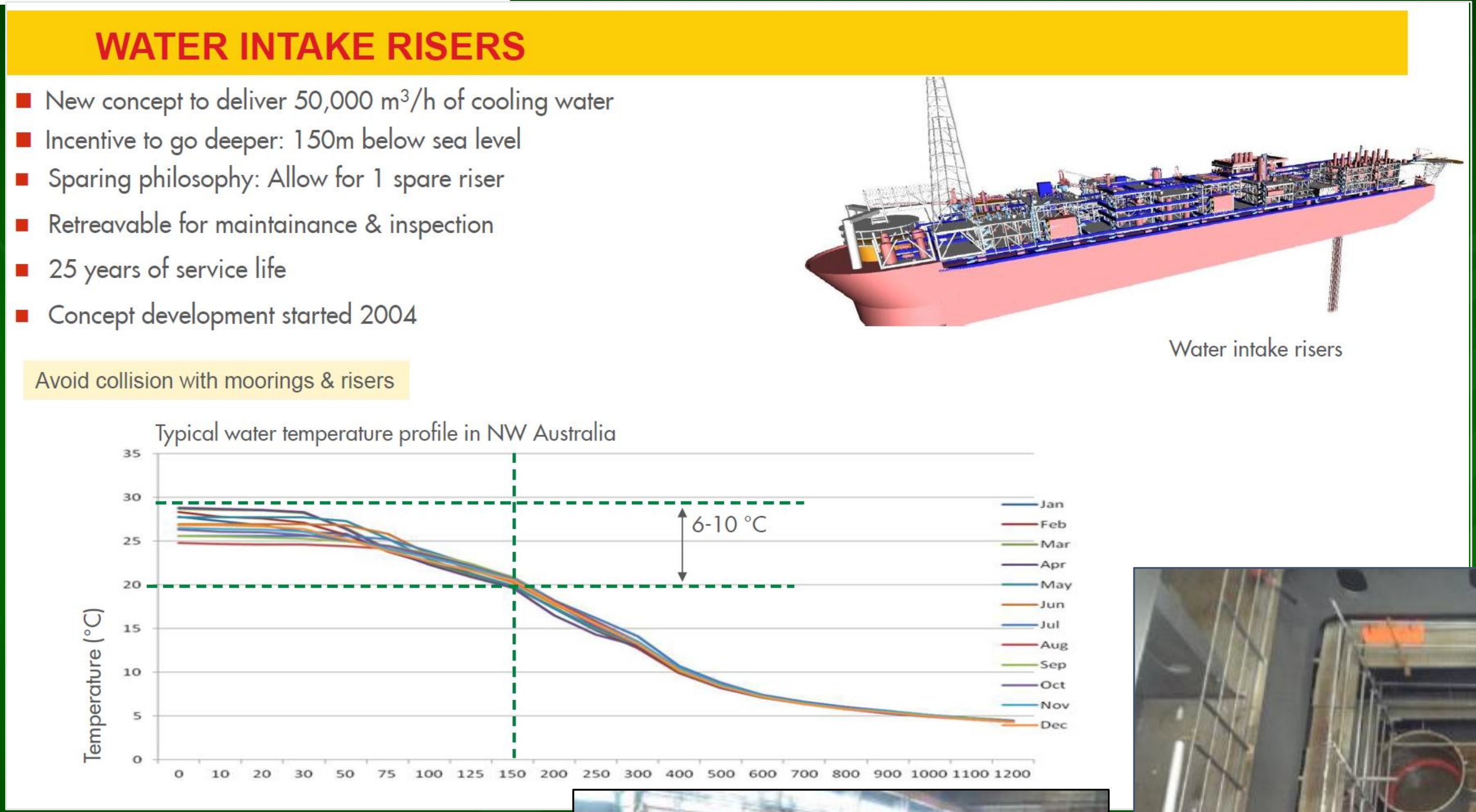
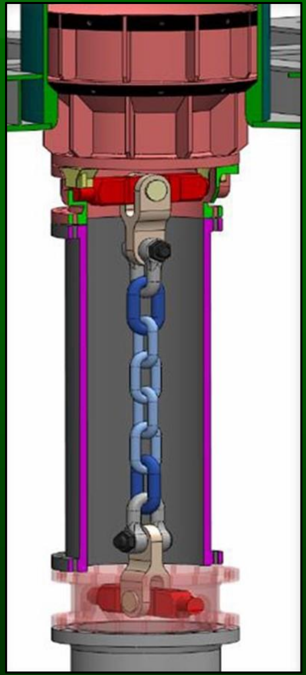
Nine (9) Deep Water Steel Risers, Shell Prelude FLNG



- Designed to survive 10,000 year environmental conditions, including tropical cyclones
- Courtesy Mike Efthymiou



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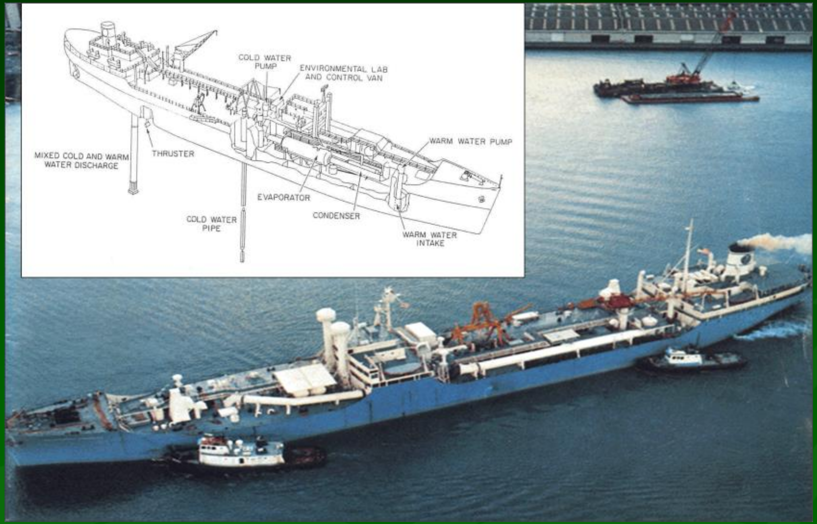
US D.of E. "OTEC 1" – Cold Water Pipe (CWP) Deployment



- Three **<u>1.2 m</u>** diam HDPE pipeline bundle, 2,250 feet long **<u>(686m)</u>**
- CWP <u>Launch, Tow and Upend</u> successfully carried out off Hawaii.
- **<u>3 pipe bundle, custom desiged large GIMBAL at top</u>**

1980/1 OTEC-1

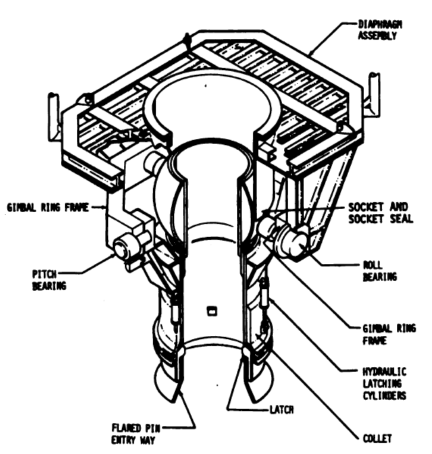
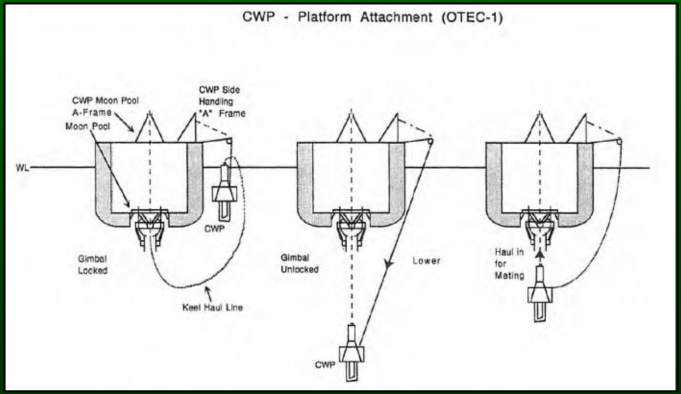


Figure 11. Gimbal/Diaphragm Assembly.



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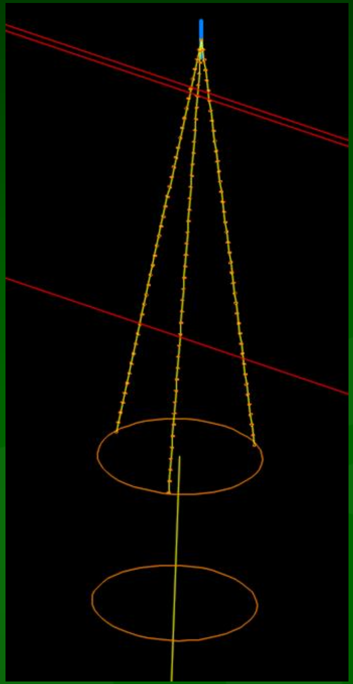
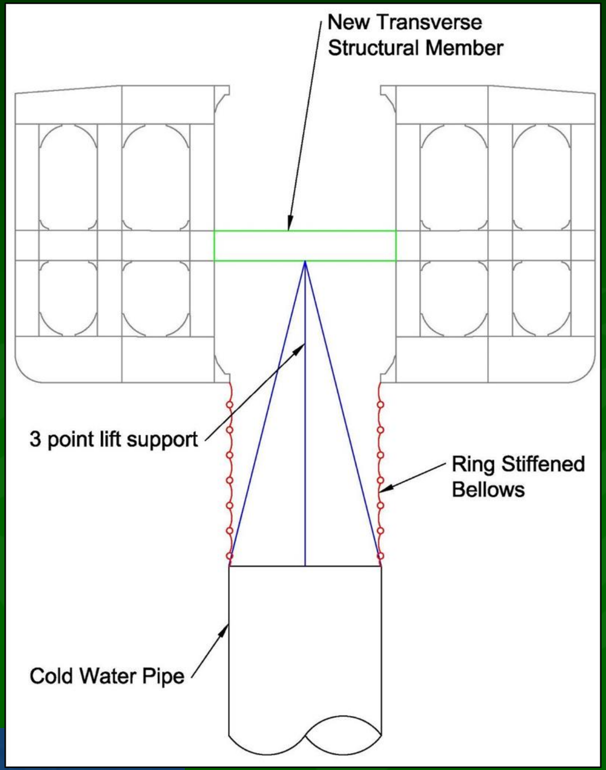
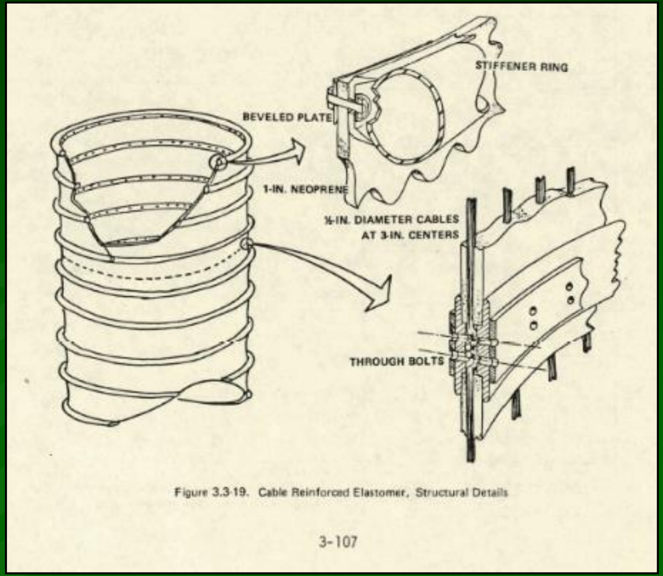
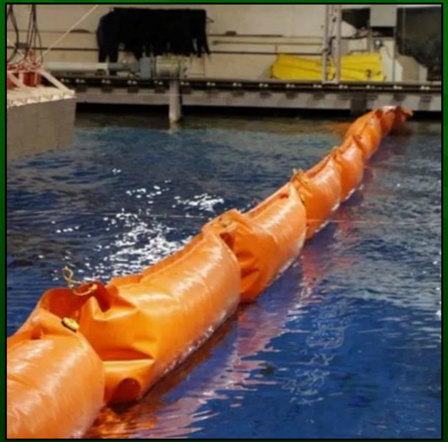
CWP Step Change - New 3 Point Decoupling Joint

- Attachment has to cope with six degrees of freedom movement
- Decouples platform motions from the CWP
- Flexible bellows provides continuity for transport of cold sea water to the surface platform

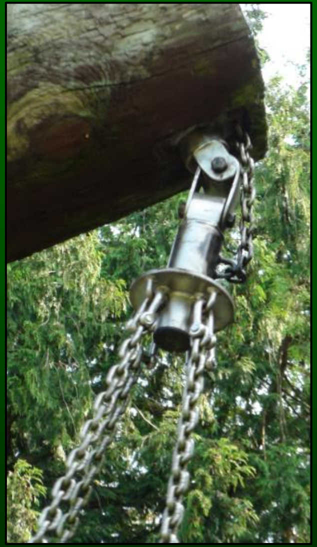






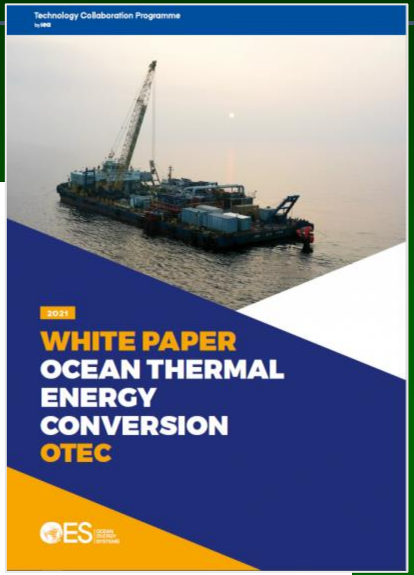


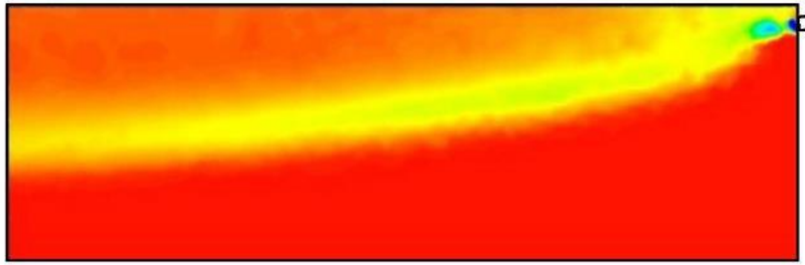
MARIN

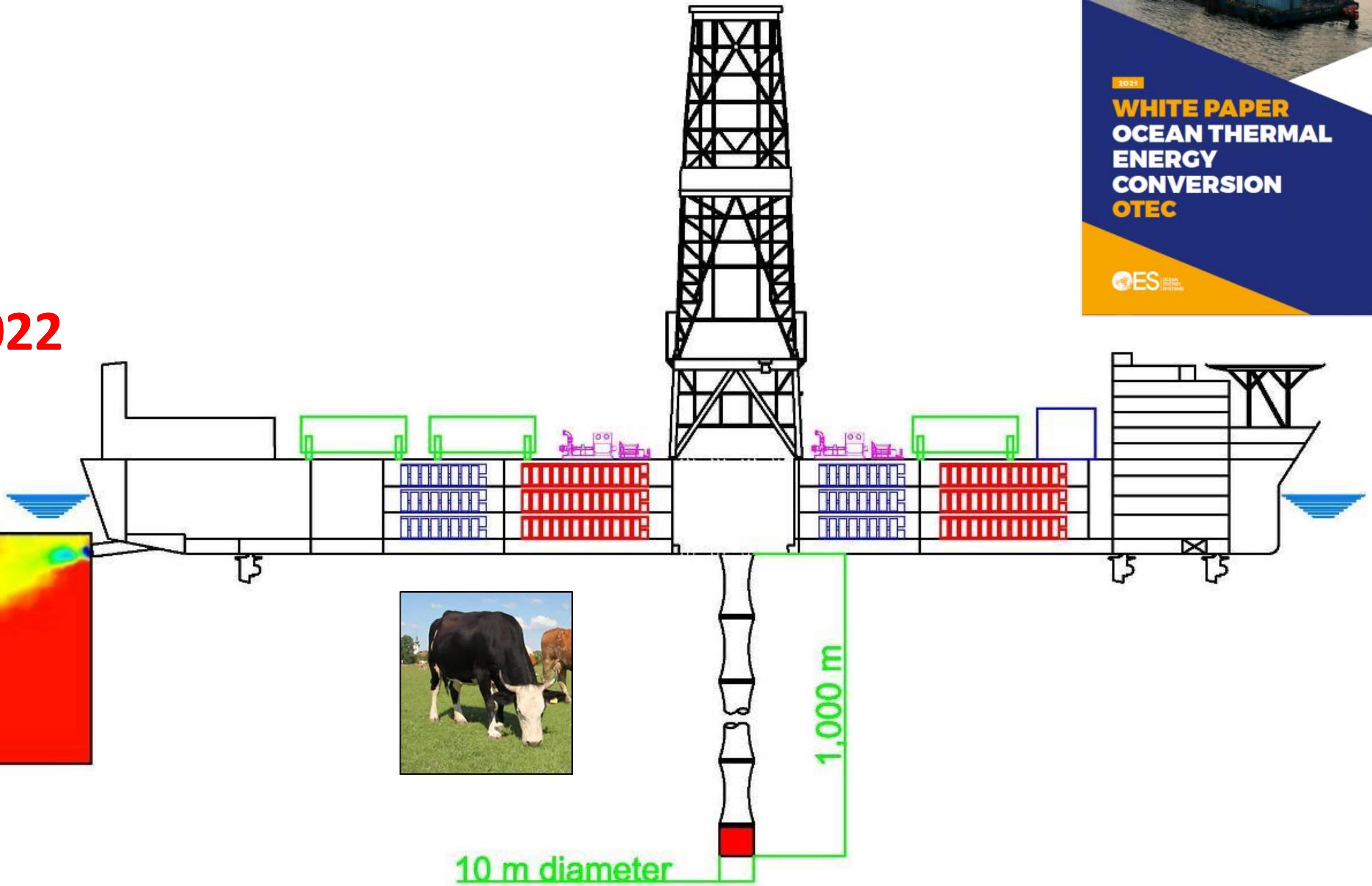


Non Moored "Grazing" Via Discharged Warm & Cold Water

Brown, M,. Brown, G.
OTC-31756-MS, **May 2022**







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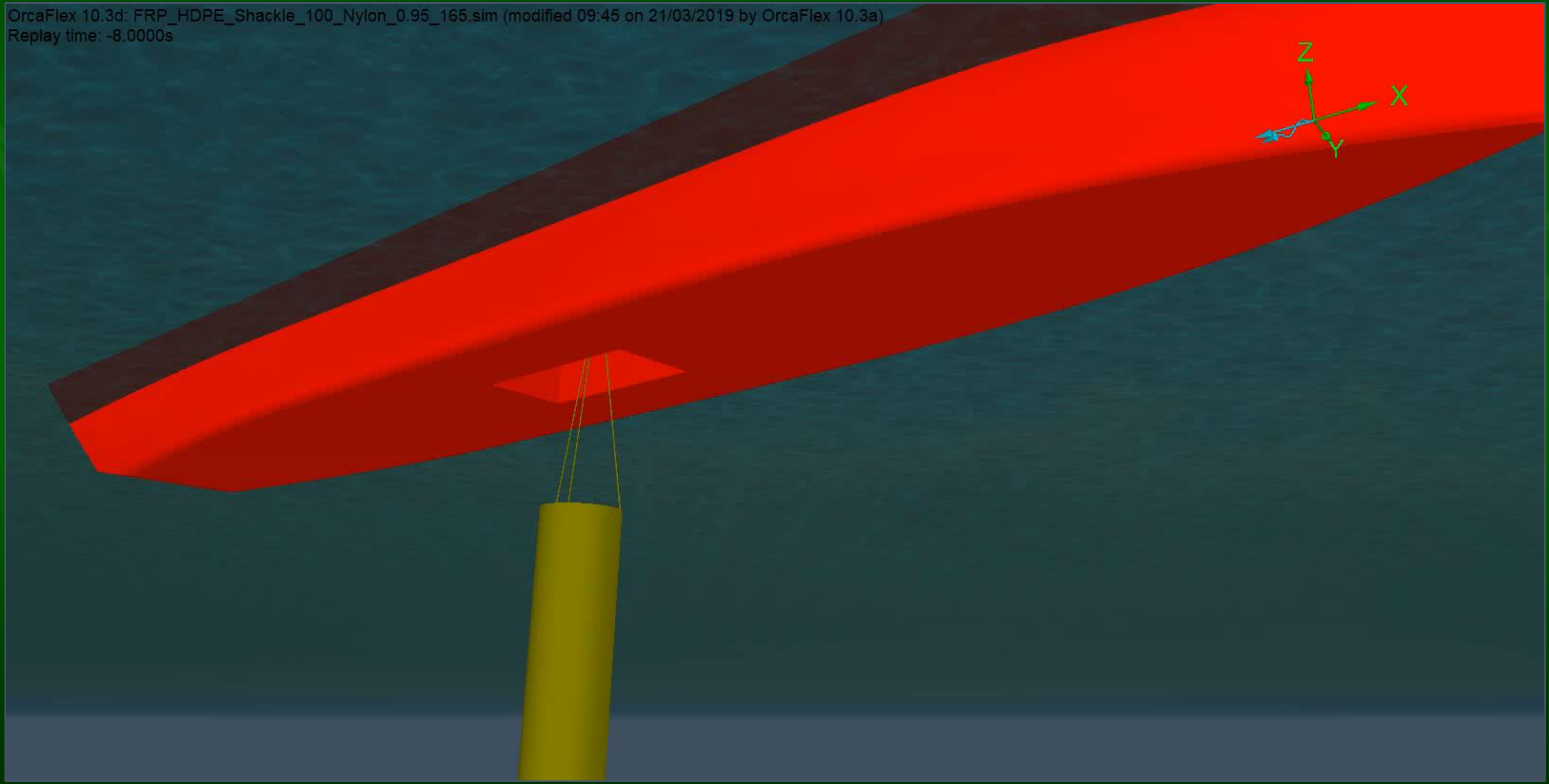
Video Orcaflex Dynamic 100 year Cyclone Simulation – Within Allowable Values



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JIP OBJECTIVES

- Resolve CWP (Cold Water Pipes) design issues for different pipe sizes
- Develop detailed design guidelines for numerical modelling and analysis of CWP designs
- Generating experimental and field data for free hanging pipes – calibrate models
- Develop a solution for gimbal or other connections of CWP with floating unit
- Propose installation procedures for CWP plus in situ inspection & repair
- Investigation of alternative materials
- Advance CWP Technical Readiness Level (TRL)

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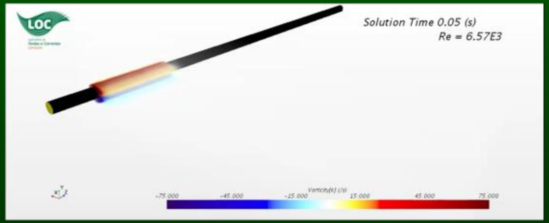
Outline Roadmap/ TRL Development

Phase 1

Pipe sizing study.
Past projects.
Numerical model
Small scale tests at FLUME (LOC)
Hydrodynamic Analysis

API17N : TRL2



Phase 2

Big scale tests at DEEP WATER OCEAN BASIN (LABOCEANO) – possibly Phase1

Structural analysis

API17N : TRL4

OTEC CWP TESTS AT LABOCEANO (2009)
SOURCE: LOCKHEED MARTIN
AND DOE

Phase 3

Field tests With Instrumented Hanging Pipe at Campos Basin from existing asset

Approval in Principle from Class

NAVCON RISER SENSORS

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Cold Water Pipe JIP

Please get in contact if of interest

LABORATORY OF WAVES AND CURRENTS

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