User Project TETRA Wave Power - Concept Test in regular
and irregular waves (Stage 1)

Project Acronym TETRA Wave Power

Project Reference Number 1463

Infrastructure Accessed Aalborg - Wave Basin

Infrastructure Access Reports

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MaRINET2

ABOUT MARINET

The MaRINET2 project is the second iteration of the successful EU funded MaRINET Infrastructures Network, both of which are coordinated and managed by Irish research centre MaREI in University College Cork and avail of the Lir National Ocean Test Facilities.

MaRINET2 is a €10.5 million project which includes **39 organisations** representing some of the top offshore renewable energy testing facilities in Europe and globally. The project depends on strong international ties across Europe and draws on the expertise and participation of **13 countries**. Over 80 experts from these distinguished centres across Europe will be descending on Dublin for the launch and kick-off meeting on the 2nd of February.

The original MaRINET project has been described as a *"model of success that demonstrates what the EU can achieve in terms of collaboration and sharing knowledge transnationally".* Máire Geoghegan-Quinn, European Commissioner for Research, Innovation and Science, November 2013

MARINET2 expands on the success of its predecessor with an even greater number and variety of testing facilities across offshore wind, wave, tidal current, electrical and environmental/cross-cutting sectors. The project not only aims to provide greater access to testing infrastructures across Europe, but also is driven to improve the quality of testing internationally through standardisation of testing and staff exchange programmes.

The MaRINET2 project will run in parallel to the MaREI, UCC coordinated EU marinerg-i project which aims to develop a business plan to put this international network of infrastructures on the European Strategy Forum for Research Infrastructures (ESFRI) roadmap.

The project will include at least 5 trans-national access calls where applicants can submit proposals for testing in the online portal. Details of and links to the call submission system are available on the project website www.marinet2.eu

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1 Introduction & Background

1.1 Introduction

TETRA Wave Power is a conceptual new wave energy converter, which is based on a geometric structure that provides both strength and flexibility. With its modular and enclosed design, we believe it will overcome several of the disadvantages of the prior art for extracting the energy in ocean waves.

Øyvind Haaheim is the inventor of the concept, and the development has so far been performed by Øyvind and Helene Haaheim from their start-up company based in Norway.

The wave energy converter is named TETRA Wave Power due to the tetrahedrons which are the building blocks of the structure. Each tetrahedron module is extended by four linear actuators, similar to how carbon atoms are arranged in a diamond. 30 tetrahedrons are interconnected at pivot joints to form a symmetrical compliant frame structure, geometrically optimal for distributing axial forces from any direction, also for irregular sea.

An outer flexible membrane supports and encloses the compliant frame structure thereby defining an inner air filled volume and providing buoyancy to the WEC, which will be semi-submerged in water. The linear actuators will generate power by being respectively compressed and elongated, when the floating compliant vessel is deformed, changing the relative positions of the pivot joints. Power circuits are arranged within the inner space, connected to the linear generators to receive the power output. The compliant vessel is deformed by the waves acting on the outer flexible membrane between a steady-state condition wherein the linear actuators are in neutral positions and a deformed condition wherein at least some of the linear actuators are compressed or elongated. TETRA Wave Power can be located offshore or near shore.

1.2 Development So Far

According to the Development Protocol, the technological development is in Stage 1 (TRL 1-2).

1.2.1 Stage Gate Progress

Previously completed: ✓

Planned for this project: ➲

STAGE GATE CRITERIA	Status
Stage 1 – Concept Validation	
• Linear monochromatic waves to validate or calibrate numerical models of the system (25 – 100 waves)	➲
• Finite monochromatic waves to include higher order effects (25 –100 waves)	
• Hull(s) sea worthiness in real seas (scaled duration at 3 hours)	➲
• Restricted degrees of freedom (Dof) if required by the early mathematical models	
• Provide the empirical hydrodynamic co-efficient associated with the device (for mathematical modelling tuning)	➲
• Investigate physical process governing device response. May not be well defined theoretically or numerically solvable	➲
• Real seaway productivity (scaled duration at 20-30 minutes)	
• Initially 2-D (flume) test programme	
• Short crested seas need only be run at this early stage if the devices anticipated performance would be significantly affected by them	➲
• Evidence of the device seaworthiness	➲
• Initial indication of the full system load regimes	
Stage 2 – Design Validation	
• Accurately simulated PTO characteristics	
• Performance in real seaways (long and short crested)	
• Survival loading and extreme motion behaviour.	
• Active damping control (may be deferred to Stage 3)	
• Device design changes and modifications	➲
• Mooring arrangements and effects on motion	
• Data for proposed PTO design and bench testing (Stage 3)	
• Engineering Design (Prototype), feasibility and costing	
• Site Review for Stage 3 and Stage 4 deployments	
• Over topping rates	
Stage 3 – Sub-Systems Validation	
• To investigate physical properties not well scaled & validate performance figures	
• To employ a realistic/actual PTO and generating system & develop control strategies	
• To qualify environmental factors (i.e. the device on the environment and vice versa) e.g. marine growth, corrosion, windage and current drag	
• To validate electrical supply quality and power electronic requirements.	
• To quantify survival conditions, mooring behaviour and hull seaworthiness	
• Manufacturing, deployment, recovery and O&M (component reliability)	
• Project planning and management, including licensing, certification, insurance etc.	
Stage 4 – Solo Device Validation	
• Hull seaworthiness and survival strategies	
• Mooring and cable connection issues, including failure modes	
• PTO performance and reliability	
• Component and assembly longevity	

STAGE GATE CRITERIA	Status
• Electricity supply quality (absorbed/pneumatic power-converted/electrical power)	
• Application in local wave climate conditions	
• Project management, manufacturing, deployment, recovery, etc	
• Service, maintenance and operational experience [O&M]	
• Accepted EIA	
Stage 5 – Multi-Device Demonstration	
• Economic Feasibility/Profitability	
• Multiple units performance	
• Device array interactions	
• Power supply interaction & quality	
• Environmental impact issues	
• Full technical and economic due diligence	
• Compliance of all operations with existing legal requirements	

1.2.2   Plan For This Access

The overall objective of this access project is to demonstrate and confirm the WEC concept.

In order to document the response of the WEC under various wave conditions, motion tracking of the main nodes in the device was performed. This provides the relative displacement of the nodes, and thereby the elongation and compression of the linear actuators where the power conversion will take place. No PTO was installed in this small scale model. Rather, linear springs were mounted to represent the deformation in the linear actuators. By knowing the stiffness of the springs and the elongation, the force in the actuators as a function of incoming wave can be identified.

During the test, the plan was also to:

- Document response under regular waves for calibration of numerical models
- Investigate behavior for different mass distributions
- Observe response under 3D waves (short crested)

Technical output from the tests will be used to calibrate and revise the numerical calculations. We expect to have a better representation of the effects of the outer membrane, which has not yet been numerically described well.

The calibrated and improved computer model will then be used in a more extensive study of the interconnected parameters of TETRA Wave Power. Optimization of geometry, stiffness, damping, mass distribution and mooring configurations are necessary steps in the further development of the concept. The improved computer model will also be used to estimate a preliminary power matrix and LCOE.

1.3   The infrastructure

The infrastructure accessed for the tank tests was the Wave & Current Basin at the Department of Civil Engineering, Aalborg University.

The wave basin (Figure 1) is 14.6m x 19.3m, with an active test area of 13 x 10m. Maximum water depth is 1.2m. The basin is equipped with a long-stroke segmented piston wave-maker for accurate short-crested (3D) random wave generation with active absorption. The wave-makers are powered by electric motors which allow for less acoustic noise, no oil pollution in the basin and more accurate waves.

The tank provides a data log system, with its own hardware and software, and wave gauges with electronics and auto-tuning capabilities.
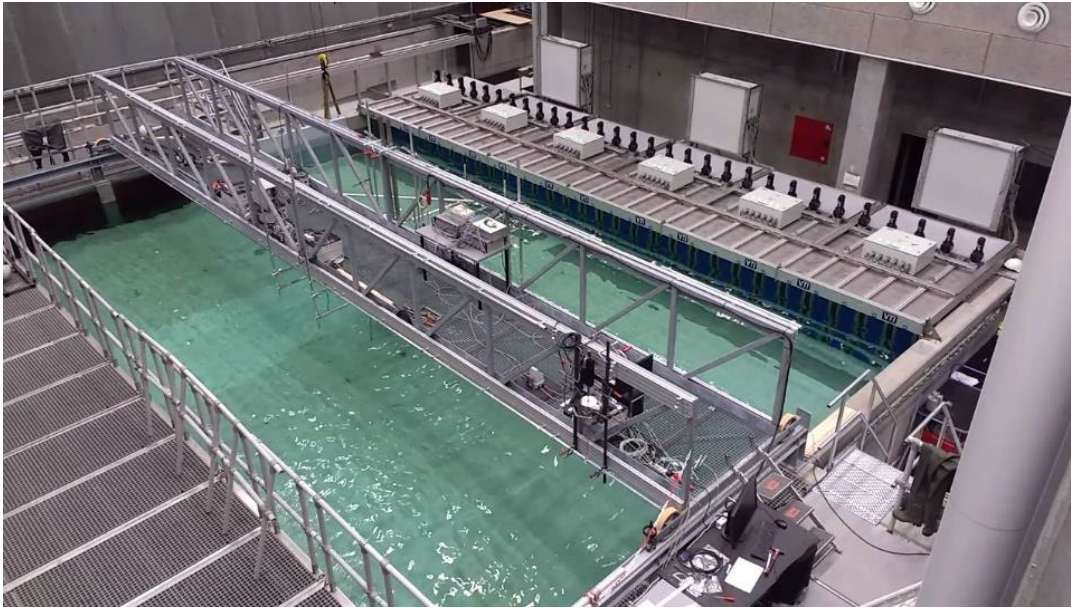
Figure 1 Aalborg University - Wave and Current Basin

2 Outline of Work Carried Out

2.1 Model

The test model has main characteristic dimension of 2 m, see Figure 2. The size of a full scale device will depend on the governing waves at deployment site, since performance of the WEC will be higher for some wave length ranges. One may assume a diameter of 50 m for full scale WEC, which corresponds to a model scale of 1:25 for this lab test.

21 reflective markers were mounted on the nodes that was accessible for this. The motion tracking system could then log the coordinates of the nodes during the tests.

The draft of the model could easily be adjusted by adding ballast.

The model was not fully enclosed by the membrane for this test, due to several reasons:

- Possibility to equip nodes in the inner space with motion tracking markers.
- Access to the inner space when changing mass configuration
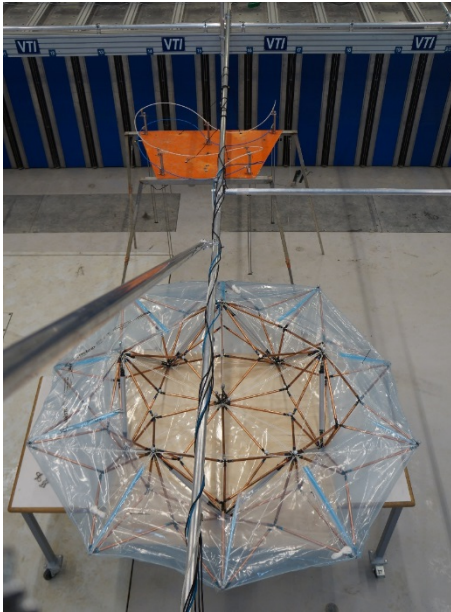- Visibility, better observation of the behavior of the inner structure

Figure 2 Test model before filling the basin

2.2 Setup

Figure 3 and Figure 4 show the test setup. The main components of the test setup are:

1. AAU facility with wave maker
2. Model scale of TETRA Wave Power, located in the center of the basin.
3. Mooring lines
4. Load cells for measuring forces in the mooring lines
5. Wave gauges in the front, at the side and behind the model
6. Motion capturing system from Optitrack, with four cameras located around the basin.
7. Action cameras to film the WEC from above and below water.

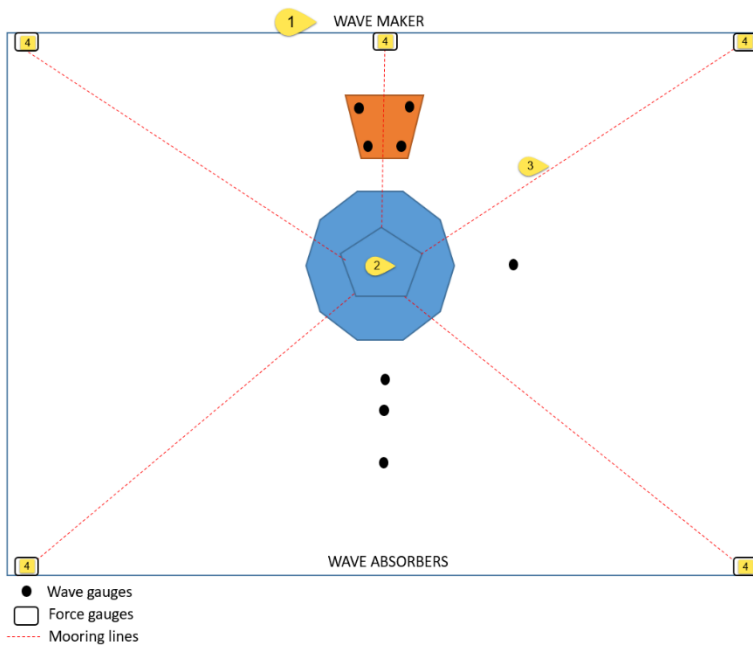The water depth during tests was 1.1 m.
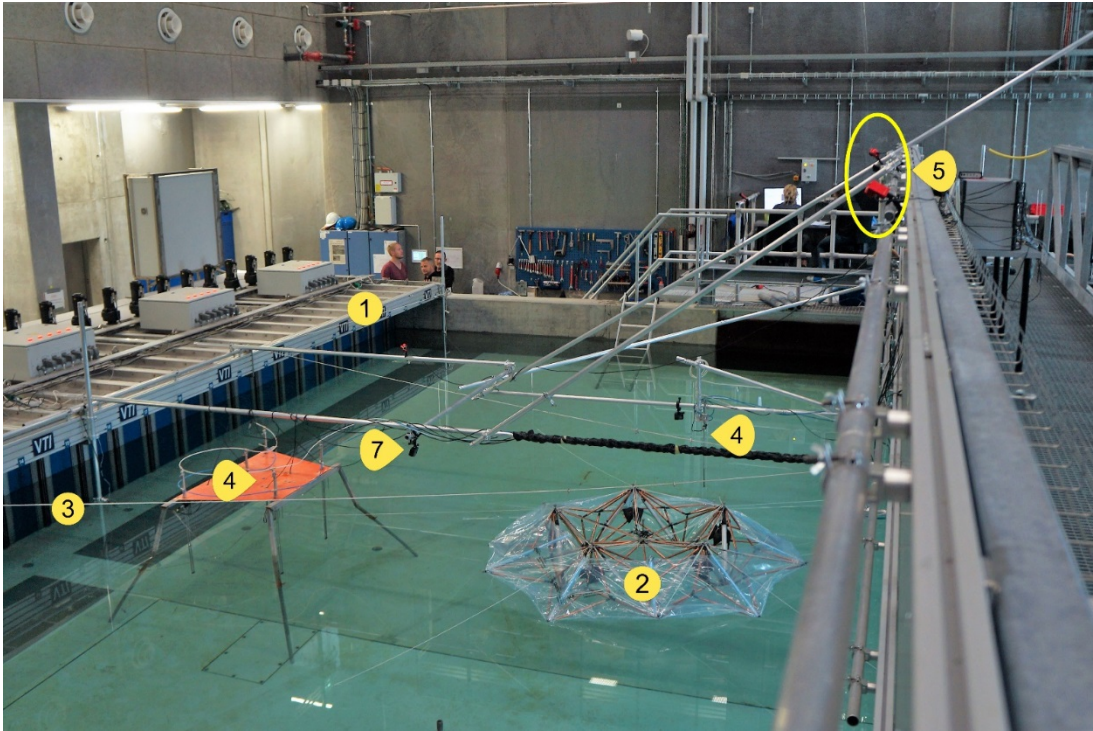

Figure 3 Schematic test setup

Figure 4 Photo of the test-setup

2.2.1 Mooring

The mooring configuration kept the WEC in place, free from drifting and rotating, but not constraining the response significantly. Five mooring lines from the five upper nodes were installed, as illustrated in Figure 5. The mooring lines were equipped with force gauges.
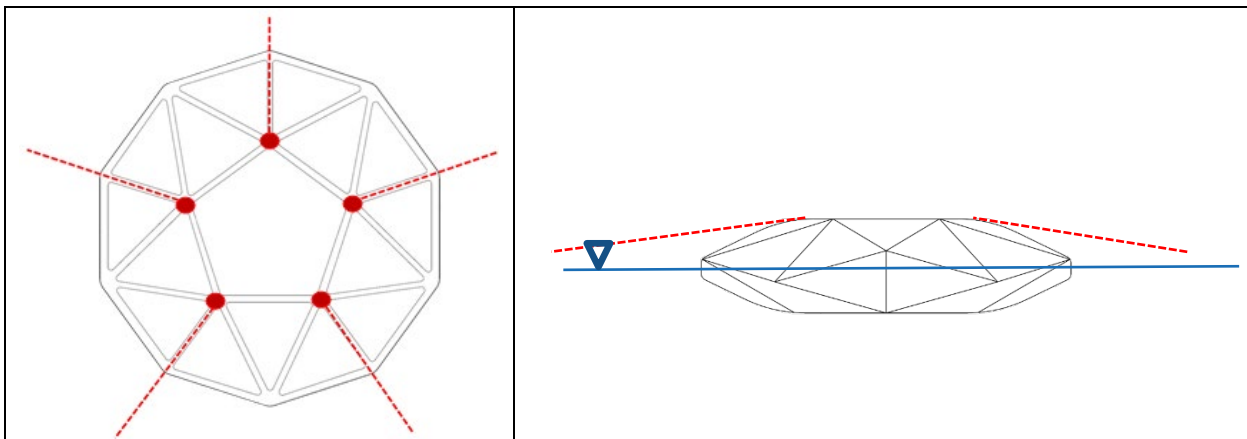
Figure 5 Mooring configuration

2.3 Tests

2.3.1 Performed test plan

The detailed test program that was set-up before the access period has been achieved with some adjustments along the way. Some additional tests and outcomes have been obtained. A coarse overview of the main performed tests is given in Table 1 and Table 2. In Table 1 the wave heights that were investigated for various mass configurations are listed, with the corresponding maximum and minimum wave periods. Within this range, the step was 0.1 sec.

Ballast configuration [kg]	H [m]	T_max [s]	T_min [s]	Heading angle [deg]
10	0.05	0.6	1.3	0
10	0.07	0.7	1.3	0
10	0.10	0.8	1.4	0
20	0.03	0.6	1.3	0
20	0.05	0.6	1.3	0
20	0.07	0.7	1.3	0
20	0.07	0.7	1.3	18
20	0.07	0.7	1.3	36
20	0.10	0.8	1.4	0
30	0.05	0.6	1.3	0
30	0.07	0.7	1.3	0
30	0.10	0.8	1.4	0
40	0.05	0.6	1.3	0
40	0.10	0.8	1.4	0
40	0.12	0.9	1.8	0
40	0.14	0.9	1.5	0
40	0.16	1.0	1.4	0
40	0.18	1.3	-	0
40	0.20	1.3	-	0
40	0.22	1.3	1.5	0
40	0.24	1.3	-	0

Table 1 Regular waves, main tests performed during the test campaign

Ballast configuration [kg]	Wave Type	Hs [m]	Tp [s]	Spectrum	Peak enhancement factor	Spreading	Duration [s]
20	Irregular	0.05	0.8	JONSWAP	2.7	45	450
20	Irregular	0.075	0.8	JONSWAP	2.7	45	500

Table 2 Irregular waves, main tests performed during the test campaign

The background for the selection of waves are described below.

Regular waves

Testing of regular waves was performed to attempt to obtain equivalent RAOs that give information about the non-linear damping of the system. These results will be used for calibration of the numerical model, and inter-/extrapolation of results purpose for further calculations.

We also wanted to run some extreme waves to observe maximum deformation of the WEC.

The selection of regular waves for testing is based on the following:

Since the character of our "vessel" is highly non-linear, establishing a traditional RAO does not make any sense. However, we wish to identify the non-linear damping effect through an iso-height test, running periods from low to high.

The steeper the wave, the more deformation of TETRA was expected, which is why the tests included as steep waves as the wave maker could generate, still keeping it in the linear domain. The larger the motion, the better data sets from the motion tracking system was expected.

We were also interested in running longer waves for quality assuring the motion tracking data sets (for long waves, the WEC should follow the waves like a rigid body), well aware that the deep water condition is no longer fulfilled for the longer periods with this water depth.

Irregular waves

TETRA Wave Power is especially adapted to 3D waves. Testing of irregular waves with spreading was performed with the objectives to observe the behavior of TETRA Wave Power under more natural conditions. See Table 2 for sea states. The irregular waves were performed assuming a scale of 1:25, and thereby run for 500 sec to ensure a 3 hour sea state.

2.4 Results

The tests are seen as successful on several regards:

- The more ballast applied, the more movement was measured. (40kg was the highest ballast tested)
- More ballast gave more pretension of the linear actuators when in neutral position, which in turn resulted in more response under waves.
- The model remained intact throughout the entire test. There was a small leakage in the membrane from the beginning, but it did not develop and was handled by emptying the small amount of water inside every morning before testing.
- The motion tracking system managed to track the nodes, despite the pollution from reflective surfaces from the water and membrane.
- The response of the centre as a function of incoming wave is plotted in Figure 6. The resonance in heave is found at t=1.26 sec, where $\frac{L_{Wave}}{L_{WEC}}$ =1.2
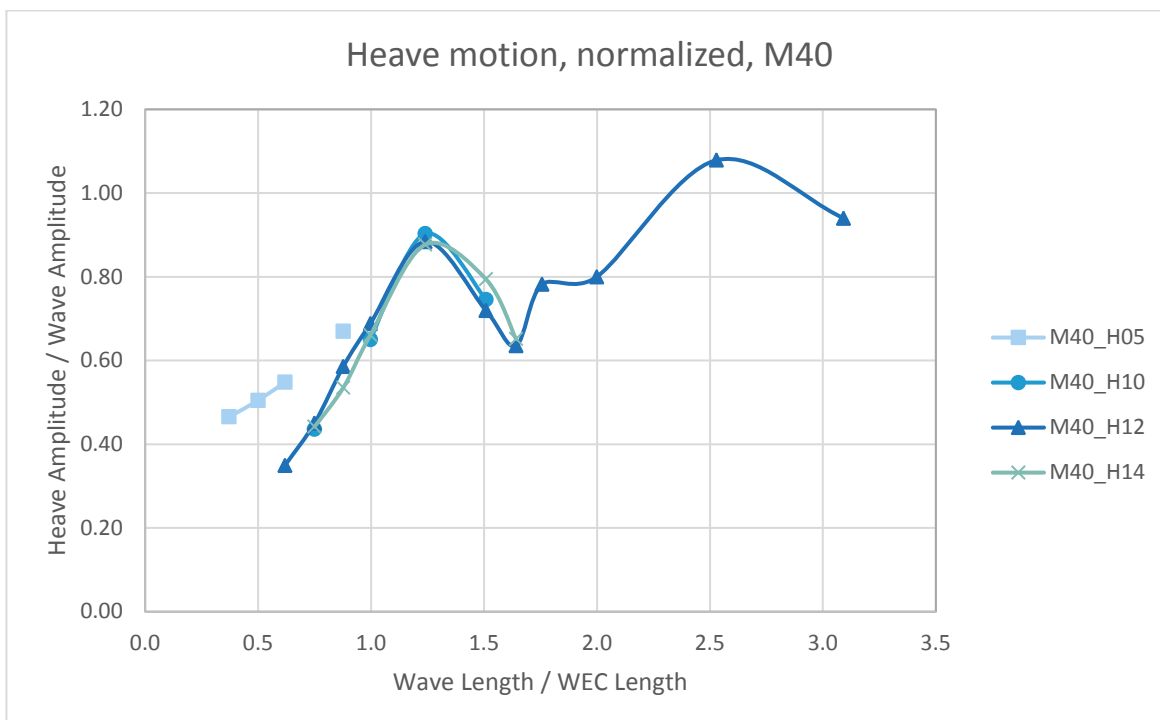

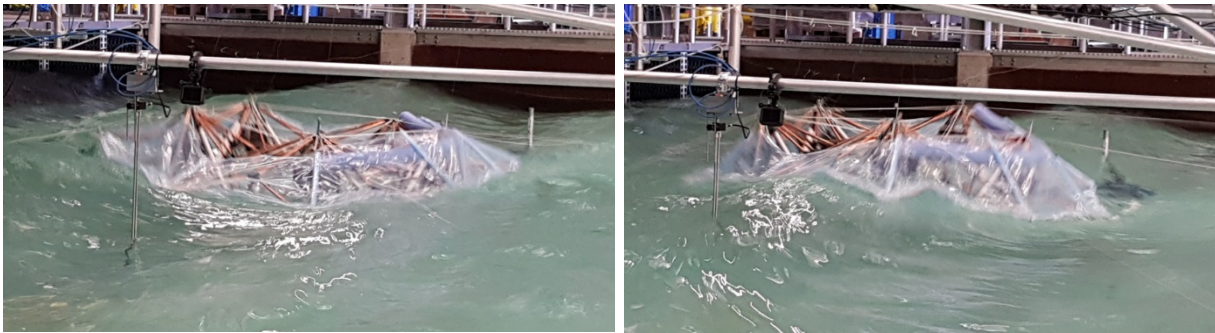**Figure 6 Heave RAO for centre node, mass configuration m=40kg**

Figure 7 Model during testing, regular waves

Note that the analysis of the relative displacements between nodes is not yet completed and is therefore not presented here. These test results will provide the force in the actuators as function of incoming wave and are essential for the estimation of the power take off (PTO) system .

2.5   Analysis & Conclusions

The staff at the Wave Basin at AAU provided very good assistance, both from the technical and the academic staff. The modern facility which allowed for rigging in an empty basin, was very beneficial for our setup and resulted in a more successful testing.

TETRA Wave Power responded as expected, signifying that the dynamic properties of the WEC was correctly designed to respond under the wave loads. Also observing that there was deformation even for longer waves, where we expected the WEC to follow the wave more like a rigid ship, rather than deforming.

Due to a lot of noise in the time series from the motion tracking system, there are still significant post-processing that will be performed of the raw data. The relative displacement of the nodes has not been analysed yet.

The results from the wave tank experiments certainly lead to a quite important step forward in the development of the TETRA Wave Power device, to be analysed in the next Stage 2 "Design Validation."

3   Main Learning Outcomes

3.1   Progress Made

3.1.1   Progress Made: For This User-Group or Technology

None of the members of the TETRA Wave Power development team had previous experience of physically testing of wave energy converters or working in a wave tank environment. The experience gained operating in close alliance with the facility provider was of considerable benefit to each of the team members.

Although the model remained operative throughout the test period, some design issues were encountered which can now be corrected in future construction operations.

3.1.1.1   Next Steps for Research or Staged Development Plan – Exit/Change & Retest/Proceed?

Following this successful completion of the Stage 1 test program, the technical development will proceed. More post-processing of the data will be performed. A refined mathematical time domain model that can

deal with short crested irregular wave excitation will be investigated. This will be validated against the MaRINET2 empirical results prior to the model's application to optimise the design.

A larger scale model with a more realistic power take-off mechanism will be designed, based on the improved calculations to begin the Stage 2 process.

3.1.2   Progress Made: For Marine Renewable Energy Industry

The setup used during the testing with 4 Optitrack cameras and 21 reflecting ball was quite successful. It provides a good benchmark of the quantity and the quality of the data that can be gathered for this WEC model size and design.
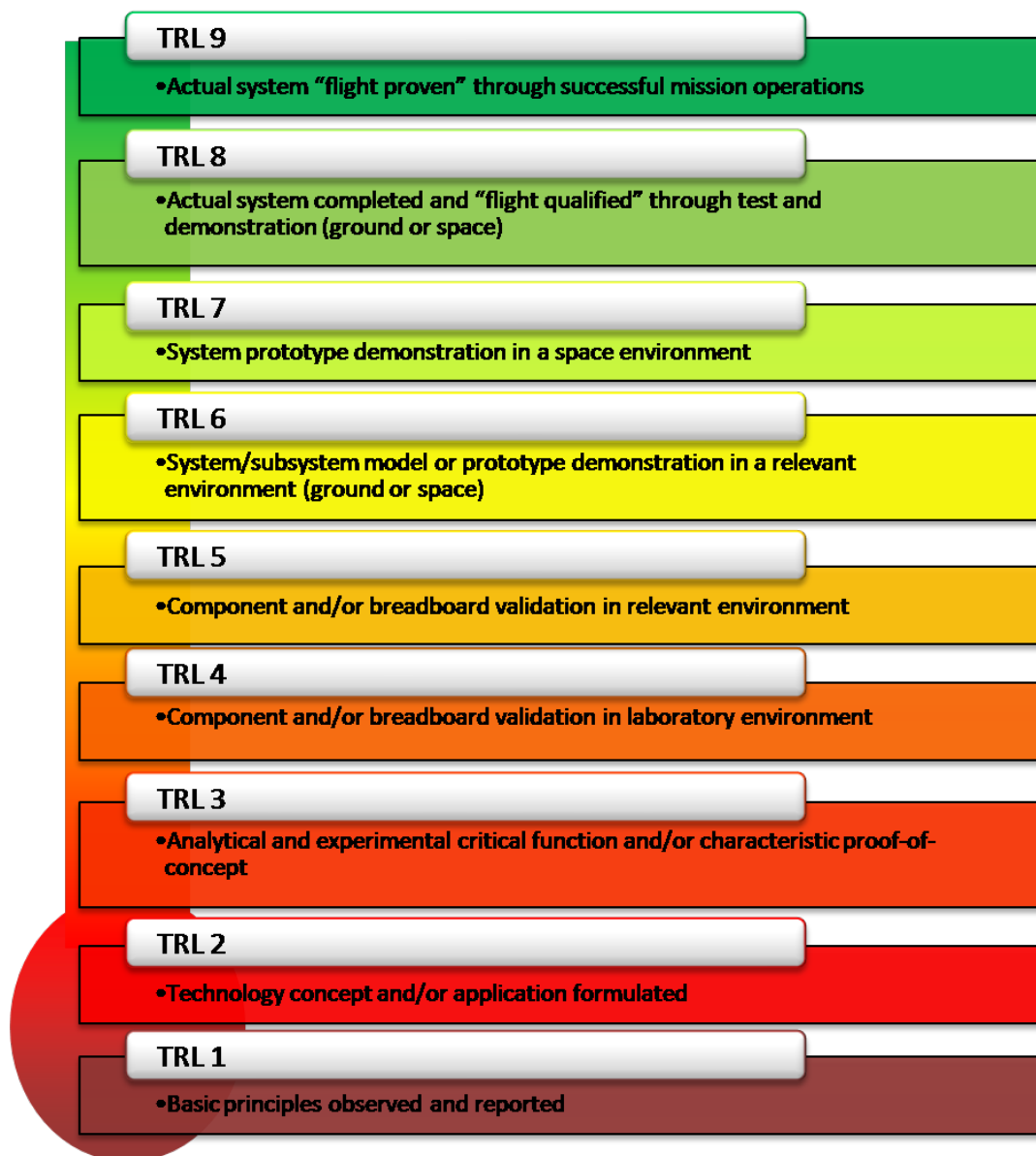
3.2   Key Lessons Learned

- Plan with sufficient time for rigging the model and setting up instrumentation (well begun is half done)
- Ensure the test plan is feasible in time and complexity for the infra-structure capability
- Make a check list for the procedure when running the tests (calibration, running wave maker, register data, camera recording etc.)
- Keep a detailed test-log, register as much information as practically possible
- Validate the raw data on a regular basis
- Perform intermediate checks of the results from the motion tracking system, to ensure that is it set up correctly
- Set action cameras on low frame rate if possible to reduce file size
- Include time to transfer files from action cameras and motion tracking system in the test plan. The files are large and data-transfer is time consuming. Correct file export is important to keep time stamp of files.
- The raw data from the motion tracking system can be cleaned in the software from Optitrack, "Motive" tracking system, which might be a good and timesaving alternative compared to other means (programming in Python, Matlab or similar)

4 Appendices

4.1 Stage Development Summary Table

The table following offers an overview of the test programmes recommended by IEA-OES for each Technology Readiness Level. This is only offered as a guide and is in no way extensive of the full test programme that should be committed to at each TRL.

TRL 9
•Actual system "flight proven" through successful mission operations

TRL 8
•Actual system completed and "flight qualified" through test and demonstration (ground or space)

TRL 7
•System prototype demonstration in a space environment

TRL 6
•System/subsystem model or prototype demonstration in a relevant environment (ground or space)

TRL 5
•Component and/or breadboard validation in relevant environment

TRL 4
•Component and/or breadboard validation in laboratory environment

TRL 3
•Analytical and experimental critical function and/or characteristic proof-of-concept

TRL 2
•Technology concept and/or application formulated

TRL 1
•Basic principles observed and reported

NASA Technology Readiness Levels[1]

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[1] https://www.nasa.gov/directorates/heo/scan/engineering/technology/txt_accordion1.html

NASA TRL Definition Hardware Description Software Description Exit Criteria

TRL	Definition	Hardware Description	Software Description	Exit Criteria
1	Basic principles observed and reported.	Scientific knowledge generated underpinning hardware technology concepts/applications.	Scientific knowledge generated underpinning basic properties of software architecture and mathematical formulation.	Peer reviewed publication of research underlying the proposed concept/application.
2	Technology concept and/or application formulated.	Invention begins, practical application is identified but is speculative, no experimental proof or detailed analysis is available to support the conjecture.	Practical application is identified but is speculative, no experimental proof or detailed analysis is available to support the conjecture. Basic properties of algorithms, representations and concepts defined. Basic principles coded. Experiments performed with synthetic data	Documented description of the application/concept that addresses feasibility and benefit.
3	Analytical and experimental critical function and/or characteristic proof of concept.	Analytical studies place the technology in an appropriate context and laboratory demonstrations, modelling and simulation validate analytical prediction.	Development of limited functionality to validate critical properties and predictions using non-integrated software components.	Documented analytical/experimental results validating predictions of key parameters.
4	Component and/or breadboard validation in laboratory environment.	A low fidelity system/component breadboard is built and operated to demonstrate basic functionality and critical test environments, and associated performance predictions are defined relative to the final operating environment.	Key, functionally critical, software components are integrated, and functionally validated, to establish interoperability and begin architecture development. Relevant Environments defined and performance in this environment predicted.	Documented test Performance demonstrating agreement with analytical predictions. Documented definition of relevant environment.
5	Component and/or breadboard validation in relevant environment.	A medium fidelity system/component brassboard is built and operated to demonstrate overall performance in a simulated operational environment with realistic support elements that demonstrates overall performance in critical areas. Performance predictions are made for subsequent development phases.	End-to-end software elements implemented and interfaced with existing systems/simulations conforming to target environment. End-to-end software system, tested in relevant environment, meeting predicted performance. Operational environment performance predicted. Prototype implementations developed.	Documented test performance demonstrating agreement with analytical predictions. Documented definition of scaling requirements.
6	System/sub-system model or prototype demonstration in an operational environment.	A high fidelity system/component prototype that adequately addresses all critical scaling issues is built and operated in a relevant environment to demonstrate operations under critical environmental conditions.	Prototype implementations of the software demonstrated on full-scale realistic problems. Partially integrate with existing hardware/software systems. Limited documentation available. Engineering feasibility fully demonstrated.	Documented test performance demonstrating agreement with analytical predictions.
7	System prototype demonstration in an operational environment.	A high fidelity engineering unit that adequately addresses all critical scaling issues is built and operated in a relevant environment to demonstrate performance in the actual operational environment and platform (ground, airborne, or space).	Prototype software exists having all key functionality available for demonstration and test. Well integrated with operational hardware/software systems demonstrating operational feasibility. Most software bugs removed. Limited documentation available.	Documented test Performance demonstrating agreement with analytical predictions.
8	Actual system completed and "flight qualified" through test and demonstration.	The final product in its final configuration is successfully demonstrated through test and analysis for its intended operational environment and platform (ground, airborne, or space).	All software has been thoroughly debugged and fully integrated with all operational hardware and software systems. All user documentation, training documentation, and maintenance documentation completed. All functionality successfully demonstrated in simulated operational scenarios. Verification and Validation (V&V) completed.	Documented test performance verifying analytical predictions.
9	Actual system flight proven through successful mission operations.	The final product is successfully operated in an actual mission.	All software has been thoroughly debugged and fully integrated with all operational hardware/software systems. All documentation has been completed. Sustaining software engineering support is in place. System has been successfully operated in the operational environment.	Documented mission operational results

DEVELOPMENT PROTOCOL	STAGE 1 CONCEPT VALIDATION			STAGE 2 DESIGN VALIDATION	STAGE 3 SYSTEMS VALIDATION		STAGE 4 DEVICE VALIDATION		STAGE 5 ECONOMICS VALIDATION
	TRL 1: Confirmation of Operation	TRL 2: Performance Convergence	TRL 3: Device Optimisation	TRL 4: Sub-Systems Assessment	TRL5: Sub-Assembly Bench Tests	TRL 6: Full System Sea Trials	TRL 7: Solo, Sheltered, Grid Emulator	TRL 8: Solo, Exposed, Grid Connected	TRL 9: Multi-device Array (3-5)
Objectives/ Investigations	Op. Verification Design Variables Physical Process Validate/Calibrate Maths Model Damping Effect Signal Phase	Real Generic Seas Design variables Damping PTO Natural Periods Power Absorption Wave to Devise Response Phase	Hull Geometry Components Configurations Power Take-Off Characteristics Design Eng. (Naval Architects)	Final Design Accurate PTO [Active Control] Mooring system Survival Options Power Production Added mass	PTO Method Options & Control Inst. Power Absorption Electricity Production & Quality	Scale effects of Overall Performance Characteristics Mooring & Anchorage Security Environmental Influences & Factors	Oper & Mains Procedures Electrical Output Quality Grid Supply, Stability & Security PTO Performance at all phases Control Strategy Seaworthiness, Survival & Lifecycle Analysis Device Array Interaction (Stages 1 & 2)		Grid Connection Array Interaction Maintenance Service Schedules Component Life Economics
Output/ Measurement	Vessel Motion Response Amplitude Operators & Stability Pressure / Force, Velocity RAOs with Phase Diagrams Power Conversion Characteristic Time Histories Hull Seaworthiness; Excessive Rotations or Submergence Water Surface Elevation Abeam of Devices			Motion RAOs Phase Diagrams Power v Time Wave Climates @ head, beam, follow	PTO Forces & Power Conversion Control Strategies	Incident Wave Field 6 D of F Body Motion & Phase Seaworthiness of Hull & Mooring [Survival Strategies]	Full On-Board Monitoring Kit for Extended Physical Parameters Power Matrix Supply forecasting	Array Interaction Annual Power Prod. Elec. Power Perfrm. Failure Rates Grid EIA reviews	Service, Maintenance & Production Monitor, Telemetry for Periodic checks & Evaluation
Primary Scale (λ)	$\lambda = 1 : 25 - 100$ (∴ $\lambda_t = 1 : 5 - 10$)			$\lambda = 1 : 10 - 25$	$\lambda = 1 : 2 - 10$		$\lambda = 1 : 1 - 2$		$\lambda = 1:1$, Full size
Facility	2D Flume or 3D Basin			3D Basin	Power Electronics Lab	Benign Site	Sheltered Full Scale Site	Exposed Full Scale Site	Open Location
Duration –inc Analysis	1-3months	1-3months	1 3 months	6 – 12 months	6 – 18 months		12 – 36 months		1 – 5 years
Typical No. Tests	250 - 750	250 - 500	100 - 250	100 - 250	50 - 250		Continuous		Statistical Sample
Budget (€,000)	1 – 5	25-75	25-50	50 - 250	1,000 – 2,500		10,000 – 20,000		2,500 – 7,500
Device	Idealised with Quick Change Options Simulated PTO (0-∞ Damping Range) Std Mooring & Mass Distribution		Distributed Mass Minimal Drag Design Dynamics	Final design (internal view) Mooring Layout	Advanced PTO Simulation Special Materials	Full Fabrication True PTO & Elec Generator	Grid Control Electronics or Emulator Emergency Response Strategies Pre-Production Pre-Commercial		Operational Multi-Device
Excitation / Waves	Monochromatic Linear (10-25Δƒ) (25-100 waves)	Panchromatic Waves (20min scale) +ve 15 Classical Seaways Spectra Long crested Head Seas		Deployment -Pilot Site Sea Spectra Long, Short Crested Classical Seas Select Mean wave Approach Angle		Extended Test Period to Ensure all Seaways inc.	Full Scatter Diagram for initial Evaluation Continuous Thereafter Time & Frequency Domain Analysis		
Specials	DofF (heave only) 2-Dimentional Solo & Multi Hull	Short Crest Seas Angled Waves As Required	Storm Seas (3hr) Finite Regular As required	Power Take-Off Bench Test PTO & Generator	Device Output Repeatability Survival Forces	Salt Corrosion Marine Growth Permissions	Grid Emulator Quick Release Cable Service Ops	Stakeholder Consult. Health & Safety Issues	Small Array (Up-grade to Generating Station)?
Maths Methods (Computer)	Hydrodynamic, Numerical Frequency Domain to Solve the Model Undamped Linear Equations of Motion		Finite Waves Applied Damping Multi Freq Inputs	Time Domain Response Model & Control Strategy Naval Architects Design Codes for Hull, Mooring & Anchorage System. Economic & Business Plan			Economic Model Electrical Stab. Array Interaction	Grid Simulation Wave forecasting	Array Interaction Market Projection for Devise Sales
	EVALUATION [Stage Gates]								
Absorbed Power Converted [kW]									
Weight, [tonnes]									
Manufacturing Cost [€]									
Capture [kW/tonne] or [kW/m^3]	[200-50 m^3]								
Production [c/kW]	< 25 €c / kW			≤ 15 €c / kW			≤ 10 €c / kW		≤ 5 €c / kW