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Tender Document TD02 Annex A: Phase 1 Testing

Section A: Overview

Section A.1: Phase 1 Tank Testing Requirements

Phase 1 tank testing is subject to the following requirements:

- Maintain compliance with the Stage 2 requirements outlined in the IEC technical specification "62600-103: Pre-Prototype Testing".
- Test an accurate, scaled representation of the Phase 3 WEC device.
- Perform tests to measure and understand:
  - Performance in operational conditions, covering the breadth of the power matrix for the target site.
  - Key device motions and behaviour.
  - Key structural loads.
- Obtain data to validate simulations and numerical modelling.
- Test in a set of mandatory long-crested and short-crested wave conditions.

To achieve these requirements, it is expected that:

- Initial characterisation tests should be completed to assess key RAOs, for example pitch, roll, heave response and decay tests, and a sweep of regular waves of varying frequency and amplitude.
- Sample rates of up to 100Hz are used, to be sufficient to measure motions for energy capture.
- The PTO model and its associated control strategies shall be equivalent, or as close to equivalent as possible, to those expected to be used during Phase 3 operation [1].
- There is similitude to the proposed Phase 3 mooring arrangement during all testing [2].
- Multiple runs of the same sea states may be completed to determine optimal control input.

Section A.2: Tank Locations

Tank testing should take place at either FloWave or IHCantabria.

The full scope for the tank testing campaign should be discussed and agreed with the tank facility.

Section A.3: Scale

Tank testing should be conducted at an appropriate scale, taking into consideration:

- Representation of the device and its mode of power conversion;
- Suitability of scaled water depths at the wave basins for the BiMEP and EMEC test sites;
- Ability for the wave basin to generate the defined mandatory wave conditions.

To correspond to a minimum of 50m full-scale water depth at FloWave, it is expected that the tests will be completed at 1:25 scale. The IHCantabria basin does not have a fixed floor, and so

[1] Control strategies may include, but are not limited to, coulomb, ideal linear, higher order and/or (re)active control strategies. Limitations may occur due to aspects relating to non-linear scaling occurs, or operations within control algorithms, and these should be indicated and tackled pragmatically where necessary.

[2] Note, that this is a more strenuous requirement than set out in the IEC TS 62600-103.

may accommodate wider variations in scale.

It is noted that developers may need to adopt a scale outside of the range of 1:15 – 1:25, as recommended for Stage 2 in the IEC 62600-103, in order to meet the tank testing requirements in the EuropeWave PCP.

Section B: Mandatory Performance Tests

Section B.1: Objective

The primary objective of the performance testing in the mandatory wave conditions in Phase 1 is to measure device performance in a set of consistent environmental conditions that are reflective of the BIMEP and EMEC test sites, utilising a representative scaled model of the structure, PTO, mooring and station keeping, and device control strategies which result in a relevant system response.

Section B.2: Outputs

The following outputs are expected from the performance tests in mandatory wave conditions:

- Contribution towards an overall Phase 1 testing report which presents the methodology, outcomes, test data, analysis and critical interpretation of results.
- Raw and interrogated data recorded for each of the mandatory wave conditions should be supplied to the buyers group.
- Detailed instructions on the data processing required for analysis of the data from the mandatory wave conditions should be supplied, including any filters and scaling, to a level where the process can be repeated reliably if required.

Section B.3: Mandatory Wave Conditions

The buyers group have identified the minimum requirements for testing in regular waves and defined a set of specific mandatory irregular sea states.

The following requirements shall be followed during the mandatory performance test programme:

- Carry out the performance tests in a single block.
- Test in all specified regular waves and irregular sea states.
- A single regular wave should be run before testing and at the end of the testing block, or prior to resumption of testing following any interruptions to the testing block (e.g. end of day, and upon resumption the following day).
- Physical characteristics of the device should not be changed between sea states during the mandatory performance tests.
- Tests can be run as many times as required, should there be data logging issues or opportunities for additional optimisation identified.

The data captured in these conditions must be supplied to the buyers group following the conclusion of testing, in addition to records of the processing that is followed and the data 'cleaning' that is employed.

Section B.3.1: Regular Waves

A minimum of 30 regular wave tests should be completed, consisting of frequency sweeps of 10 periods at 3 different wave amplitudes. The duration of each test should be for a minimum of 50 wave cycles once start-up transients have decayed and the wave is fully developed at the model location. The specific period and amplitude values shall be selected by the developer, in consultation with the wave basin facility.

Section B.3.2: Irregular Sea States

The irregular sea states are indicated in the table below.

ID	IEA ID [3]	T (sec)	H (m)	T_p (sec) $\gamma = 1.0$, $T_p = 1.1648T_e$	T_e (sec) $\gamma = 3.3$, $T_p = 1.12T_e$	H_{mo} (m)	γ [4]	Θ_m [5] (°)	s [6]	Minimum wave cycles
EW-R1	R02	6.5	1.5					0		50 + 10%
EW-R2	R10	8.5	3.5					0		50 + 10%
EW1				6.3	5.4	1.5	1.0	0	∞	250 + 10%
EW2	IR01			7.6	6.6	1.5	1.0	0	∞	250 + 10%
EW3	IR02			10.5	9.0	1.5	1.0	0	∞	250 + 10%
EW4				11.9	10.2	1.5	1.0	0	∞	250 + 10%
EW5	IR03			13.3	11.4	1.5	1.0	0	∞	250 + 10%
EW6	IR04			14.7	12.6	1.5	1.0	0	∞	250 + 10%
EW7	IR06			7.6	6.6	2.5	1.0	0	∞	250 + 10%
EW8				9.1	7.8	2.5	1.0	0	∞	250 + 10%
EW9	IR07			10.5	9.0	2.5	1.0	0	∞	250 + 10%
EW10				11.9	10.2	2.5	1.0	0	∞	250 + 10%
EW11				13.3	11.4	2.5	1.0	0	∞	250 + 10%
EW12	IR08			9.1	7.8	3.5	1.0	0	∞	250 + 10%
EW13	IR12			10.5	9.0	3.5	1.0	0	∞	250 + 10%
EW14	IR11			13.3	11.4	3.5	1.0	0	∞	250 + 10%
EW15				14.7	12.6	3.5	1.0	0	∞	250 + 10%
EW16	IR09			10.5	9.0	4.5	1.0	0	∞	250 + 10%
EW17	IR10			11.9	10.2	4.5	1.0	0	∞	250 + 10%
EW18				13.3	11.4	4.5	1.0	0	∞	250 + 10%
EW19				11.9	10.2	5.5	1.0	0	∞	250 + 10%
EW-SC1	IR14			9.7	8.6	3.5	3.3	0	6.0	1500 + 10%
EW-SC2				9.7	8.6	4.5	3.3	0	6.0	1500 + 10%
EW-SC3	IR16			9.7	8.6	3.5	3.3	0	10.0	1500 + 10%

Any concerns identified by the developer or the wave basin about the ability to achieve any of these mandatory irregular sea states should be communicated to the buyers group at the earliest possible moment, preferably before completion of model design.

Additional irregular sea state conditions are expected to be tested within the developer's overall test programme, as indicated in Section A.

Section B.4: Mandatory Testing Duration

At 1:25 scale, the mandatory performance tests should have a total cumulative duration of approximately 12 hours, corresponding to 1.5 days of the developer's overall test programme. This can be achieved once the model is operating correctly, providing there are no issues with the continuous operation of the tank. This estimated timing assumes:

- A 30 second ramp-up at the start of the sea state,
- A consistent duration for all irregular long-crested and short-crested sea state tests, which allows a minimum of 250 wave cycles + 10% for irregular long-crested sea states,

[3] "IEA ID" indicates wave conditions stated in the IEA-OES "Framework for Ocean Energy Technology".
[4] JONSWAP spectrum enhancement factor.
[5] Mean wave direction, relative to the device.
[6] Spreading factor in directional distribution function, $cos^{2s}[(\theta - \theta_m)/2]$.

and, 1500 wave cycles + 10% for irregular short-crested sea states. This ensures all tests are compliant with the minimum wave cycle requirement specified in the IEC, once start-up transients have decayed and the sea state is fully developed at the model location.

- A settling time between sea states of 5 minutes (300 seconds).

Use of a consistent duration can also reduce the risk of error when using the DAQ recording times at test facilities.

Section C: Independent Review

Phase 1 performance testing will include a review of the testing activities by an accredited third party, independent of, but organised by, the developer.

Where the wave basin facility has been contracted to design and run the test campaign on behalf of the developer, their scope of services can also include this review.

Where the developer is designing and running their own test programme, the suitability of the independent third party to fulfil this review role should be fully justified.

The review will require sight of the planning, methodology, and outputs of all Phase 1 tank testing activities, so it is possible to provide an objective assessment of the overall test campaign and how it complies with best practice.

The scope of the review activities should cover the following as a minimum:

- Consider and comment on the adherence of the overall testing programme (including model design, and testing implementation) to guidelines presented in IEC 62600-103, and its suitability to deliver appropriate data for performance estimation and modelling validation.
- Witness mandatory performance testing.
- Ensure that the tests follow the requirements outlined in Sections A and B of this document.
- Consider the suitability of scaling of the model and the test environment, any compromises introduced, and comment on any challenges associated with extrapolating these to the anticipated full-scale behaviour. This should include, but not be limited to:
    - Environmental conditions (waves, depth, tidal conditions (where appropriate), etc.)
    - Device structural design
    - Approximation used for the power take-off
    - Control/damping methodology
    - Station keeping system characteristics
- Comment on the quality of the measured data, which may consider e.g. instrument calibration, wave calibration, synchronisation of systems/timestamps, experimental noise, quantification of measurement errors, testing uncertainties, etc.

The output of the review work will be a report delivered to the developer and the buyers group.