MaRINET2

[T2.7 Test Requirements]

Final guidelines for test facilities

Deliverable 2.7: Final guidelines for test facilities

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Contents

Executive summary

This guideline provides recommendations to testing bodies involved in marine renewable energy (MRE) development, addressing appropriate standards and documentation to support testing of MRE technologies. This deliverable constitutes an output of Work package 2 of the Marinet2 project dedicated to gathering the experience of the international partners in testing and technology assessments.

The MRE industry is a relatively young field and standardisation of best practices and technical specifications development is still in progress. The experience of testing facilities and lessons learnt from laboratories provides a foundation to agree best practice. For this reason, previous research projects, such as Marinet 1 and Equimar, have been carried out to centralise knowledge on these best practices and make them available to all stakeholders.

The document is structured as follows:

- Introduction
- Infrastructure categories and applicable standards
- Pre installation guidelines and infrastructure access rules
- Testing and technology assessment method
- Tank testing activities common practices
- Measuring results
- Reporting

For each of the sections, a general description of the relevant recommendations and guidelines will be provided as well as references to the international standards relevant to the subject. Each section will also include deliverables from other projects susceptible to assist test facilities in the relevant tasks.

1. Introduction

1.1 Scope of report

Diversity of marine energy conversion technologies induces a wide range of industry standards and procedures directed towards their development. One of the purposes of the Marinet2 programme is to make available a set of best practices for testing and development of these devices. These best practices intend to guarantee compliance with the appropriate existing industry standards, while making testing process more efficient for both test facilities and technology developers.

The current staged development approach of MRE technologies separates tested MEC technologies according to TRLs (Technology Readiness Levels) in order to assess their development level. The concept of TRL for MRE technologies has been described and developed in the Australian Renewable Energy Agency (ARENA) report (Australian Renewable Energy Agency, 2014) See Appendix 1.

Each stage is structured following a set of requirements that the concept/prototype needs to follow in order to validate the development stage. In general, a testing campaign aims at validation of a specific TRL level to reach the next one and prove reliability of the device.

Several categories of test facilities are participating in Marinet2 partnership, all of them dedicated to basin or field testing which is applicable to different development levels of marine energy technologies. The figure below taken from Marinet2 deliverable 2.3: Draft guidelines for test facilities (Marinet: Eider Robles, Deliverable 2.3: Draft guidelines for test facilities, 2018) provides an overview of several types of testing facilities and their applicable TRLs.

Figure 1-1: TRL description for offshore renewable energy definition

The TRLs provided above follow different objectives, as referenced in Marinet2 deliverable 2.3 (Marinet: Eider Robles, 2018) . They include the status of the development level and what category of testing suits most the objectives for reaching the next TRL. In addition to the previous figure, the list below shows what level of development and application corresponds to a given TRL.

- TRL1 Basic research. Principles postulated and observed but no experimental proof available
- TRL2 Technology formulation. Concept and application have been defined
- TRL3 Applied research. First laboratory tests complete; proof of concept
- TRL4 Small scale prototype built in a laboratory environment (“ugly” prototype)
- TRL5 Large scale prototype tested in intended environment
- TRL6 Prototype system tested in intended environment close to expected performance
- TRL7 Demonstration system operating in operational environment at pre-commercial stage
- TRL8 First of a kind commercial system. Manufacturing issues solved
- TRL9 Full commercial application, technology available for consumers

The Marinet2 programme, and specifically work package 2.7 aim, is to deliver a set of guidelines for implementation at test facilities that are based on the best practices learnt from the other Marinet2 work package outputs and will satisfy industry standard requirements. This document is intended as a guide to cover the requirements of the test depending on what TRL/MEC category is observed.

The objective is to cover several categories of MECs ranked in accordance to their operating environment. The guidelines will cover wave, tidal and wind energy converters at their different development stages, including reference to appropriate industry standards when performing a test linked to a specific TRL.

The constant evolution of industry standards will make this document subject to regular updates which might also be MRE industry requirements.

In general, the objective of the document is to deliver a high-level approach of the requirements for each testing step or configuration, and provide the appropriate existing documentation based on current industry standards, or previous research programs based on the same objective.

1.2 Outline of report

As mentioned above, the document is intended to provide a structured set of guidance to be observed by the test facilities when performing testing campaign on a MRE device. The guidelines cover:

1) Applicable industry standards for development of marine renewable energies (MRE) technologies.
2) Guidelines on exchanges between the testing facilities and the developers prior to installation and infrastructures access rules
3) Technology assessment methods and best practices
4) Testing best practices learnt from Marinet2
5) Measuring test results
6) Guidelines on reporting
7) Sources and references

This report will, in addition, refer to deliverables produced during previous research projects as mentioned in the reference and the bibliography sections.

2. Infrastructure categories and applicable standards

Purpose of this section is to give an overview of IEC technical specifications directed towards testing of MEC prototypes. It is assumed, in this document, that ISO/IEC documents are the ones used by developers and test facilities as a reference for compliance with industry standards. However, each section of the deliverable also refers to additional documents that could be used for the same purpose.

2.1.1 Wave field testing

IEC did release several technical specifications dedicated to testing of wave energy converters, including scaled devices and full scale prototypes. The table below provides a list of the existing IEC documentation for testing of wave devices in tank and real-sea facilities. It is expected that some documents might cover several TRL levels and/or test requirements and might therefore be used as reference in several sections.

TRL levels	Reference
5-6	IEC TS 62600-103: Guidelines for the early stage development of wave energy converters - Best practices and recommended procedures for the testing of pre-prototype devices (International Electrotechnical Commission, 2018). Note: *The IEC TS 62600-103 covers mostly TRL levels suited for tank testing, as detailed below. The document, however, also provides guidelines for initial real-sea testing of scaled prototypes prior to deployment of a mature WEC model.*
7-9	IEC TS 62600-100: Electricity producing wave energy converters – Power performance assessment (International electrotechnical commission, 2012) Note: *Used for wave field testing*

Table 1: WEC testing IEC documents

2.1.2 Tidal field testing

As for the wave section, the table below provides an overview of the existing IEC documentation for testing of tidal prototypes to full scale prototypes.

TRL levels	Reference
5-6	IEC TS 62600-202(Draft): Scale testing of tidal stream energy systems (International electrotechnical commission) Note: *This report was written when the document above was still in draft version, changes may have been applied to the version that was used to produce the deliverable. The document is also addressed to both early and mature development stages.*

7-9	IEC TS 62600-200: Electricity producing tidal energy converters – Power performance assessment (International electrotechnical commission, 2013) Note: *Used for tidal field testing*

Table 2: Tidal testing IEC documents

2.1.3 Reference tank testing standards

Most facilities follow the IEC guidelines for performing testing of marine energy devices. However, deliverables produced by previous Marinet and Equimar projects provide a synthesis of the guidelines and recommendations that can be used when testing a device from a specific category (Wind, wave or tidal,…).

The table below intends to list the existing documentation for tank testing of marine energy devices, including IEC TC114 documentation, and deliverables of previous projects directed towards the same purpose. It is expected that this list will be lengthened in the future with publications of more developed documentation.

Category	**Reference**
Wave	PD IEC TS 62600-103:2018: Part 103: Guidelines for the early stage development of wave energy converters – Best practices and recommended procedures for the testing of pre-prototype devices Marinet Deliverable 2.8 EC: Best Practice Manual for Wave Simulation (Marinet: SUTTON & HOLMES, 2015) Marinet D2.1 Wave instrumentation database (Marinet: Lawrence, et al., 2012)
Tidal	IEC TS 62600-202: Marine energy – Wave, tidal and other water current converters – Part 202: Scale testing of tidal stream energy Systems ITTC – Recommended Guidelines. Model Tests for Current Turbines. 7.5-02-07-03.9 (International towing tank conference, 2014) ITTC – Recommended Procedures and Guidelines. Uncertainty Analysis - Example for Horizontal Axis Turbines. 7.5-02-07-03.15 (International towing tank conference, 2017)

	EquiMar - Protocols for the Equitable Assessment of Marine Energy Converters Marinet2 – Deliverable 4.3-1 - Standard Testing Procedures (Tidal Energy) (Marinet2: Sanchez, et al., 2021) Marinet D2.18: Tidal Data Analysis Best Practice (Marinet: A. Grant, T. McCombes, C.M. Johnstone, 2012)
Wind	Marinet D2.20: Report on Physical Modelling Methods for Floating Wind Turbines (Marinet: Murphy, Wright, Desmond, & Lynch, 2015) ITTC report: Model test for offshore wind turbines (International towing tank conference, 2017)
All categories	Marinet Deliverable 4.01EC: Tank test related instrumentation and best practice (Marinet: Ohana & Bourdier, 2014) Marinet deliverable 2.21 Review of Mooring Testing Systems (Marinet: Johanning, Thies, & Weller, 2014) Note: *Mooring systems for tank-scaled MRE devices might be developed in accordance to the facility too specific to be covered by a general standard. The guidelines might be provided in tank testing documentations specific to the MEC categories, eg: provided in other sections of this table.*

Table 3: IEC technical specifications and relevant projects documentation for tank testing of MRE technologies

2.1.4 Assessment of MEC mooring systems

The IEC documentation for mooring of MEC system is partly inherited from other marine industries. To various extents, the same methods as the ones in the documents referenced in the following technical specification can be applied.

The document includes also specific methods for mooring analysis of MECs, including handling devices in which the mooring is integrated in the energy capture strategy.

Category	**Reference**
All categories	TS 62600-10: Marine energy. Wave, tidal and other water current converters. Assessment of mooring system for marine energy converters (MECs) (International Electrotechnical Commission, 2015)

Table 4: IEC technical specifications and relevant projects documentation for mooring analysis of MRE technologies

2.1.5 Design requirements and mechanical loads of MECs

Category	Reference
All categories	IEC TS 62600-2: Design requirements for marine energy systems (International Electrotechnical Commission, 2016) IEC TS 62600-3: Measurement of mechanical loads (International Electrotechnical Commission, 2020)

Table 5: IEC technical specifications and relevant projects documentation for design requirements and assessment of mechanical loads on marine energy converters

2.1.6 Technology development general guidelines

Category	Reference
All categories	IEC TS 62600-4: Specification for establishing qualification of new technology (International Electrotechnical Commission, 2020)

Table 6: IEC technical specifications and relevant projects documentation for MEC general technology development process

2.1.7 Electrical power quality requirements

Category	Reference
All categories	IEC TS 62600-30: Electrical power quality requirements (International Electrotechnical commission, 2018)

Table 7: IEC technical specifications and relevant projects documentation for MEC general technology development process

3. Pre installation guidelines and infrastructure access rules

The purpose of this section is to address the points that should be followed prior to installing MRE devices in test site infrastructures. The process goes through initial contact with the developer, and initiation of the commissioning and installation phase in the facility. The guidelines presented here include recommendations of industry standards as well as best practices put in place in the previous research programs.

3.1 Transnational access

Transnational access procedure was put in place in previous Marinet2 work package 3.1b to ease and standardise the process of application for testing in test facilities for developers. The main objective of the Marinet2 transnational access is to offer to the users free-of-charge access to the research and testing facilities network.

The following section synthetizes instructions for transnational access as provided in Marinet2 deliverable 3.1b (Marinet2: Christophe Maisondieu & Alan Tassin, 2017) and describes how they should be provided by test facilities to the clients and developers willing to enter Marinet2 program. The purpose is here to address all outcomes of the deliverable, which can be found in the document itself, but to refer to the relevant sections of the deliverable using a step by step description.

In addition, the web address of the rules and procedures for Marinet2 should be shown to their clients: http://www.marinet2.eu/facilities/rules-procedures/

The high-level process flowchart of the application process is provided below as shown in (Marinet2: Christophe Maisondieu & Alan Tassin, 2017). The duration assumed for each process step is based on observation made for previous applications.

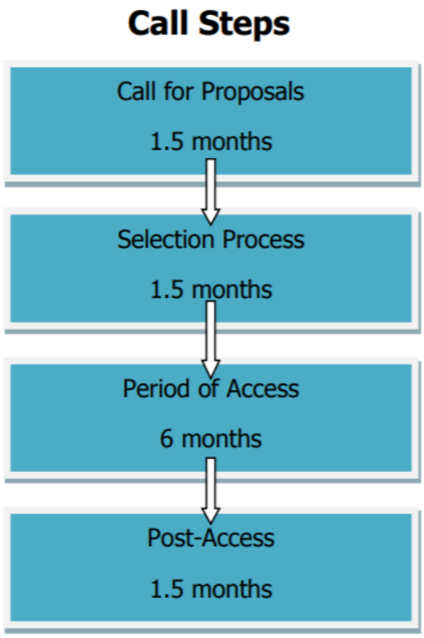

Figure 3-1: Steps procedure and expected duration as described in (Marinet2: Christophe Maisondieu & Alan Tassin, 2017)

The measures to be adopted by the client are sufficiently described in the corresponding deliverable. Purpose of the table below is to highlight the aspects on which test facilities should focus on when processing applications from their clients through the Marinet2 process.

Step	**Instruction for test facilities**
Application procedure	The application procedure must go through the dedicated web portal available on Marinet2 website. In general, the only instruction at that stage for test facilities is to answer the clients questions regarding suitability of their facility for the client's objectives.
Application form	Prior to filling the application form, it is recommended that test facilities assess clearly with the client why their facility was chosen to perform the test. Compliance with table 1 of (Marinet2: Christophe Maisondieu & Alan Tassin, 2017) shall be checked after completion of the document by both parties.
Eligibility assessment	Assess eligibility of the applicant by checking that they meet the requirements listed in section 3.1 of WP3 deliverable (Marinet2: Christophe Maisondieu & Alan Tassin, 2017).
Technical assessment	The technical assessment vows to evaluate the feasibility of the test plan regarding the device's parameters. This step is detailed in section 3.2 and is supposed to use questionnaire presented in 3.2.

	This requirement is directly addressed to test facilities and needs therefore few adaptations. This step outlines, however, the necessity of a clear information exchange between client and the test site regarding the technical parameters of the MEC, especially the aspects regarding integration of the device to the test environment. It is recommended that the test facility lists, prior to technical assessment, the specific items for device integration related to the facility and the device itself. In general, all specificities of the test equipment that could represent an obstacle to a proper installation should be listed and mitigated.
Proposals scientific Assessment	The scientific assessment step is a lesser concern for the test facility, but the points explored in the scientific assessment should be checked by the test site operations management. In many facilities the lab operator may be used to delivering scientific objectives on behalf of the client, however, the number of inputs at that stage makes it difficult to formulate a general view of the requirement.
Notification of funding decision	The test facility will participate in the funding decision by giving their input in terms of suitability for the presented applications, if they meet their requirements. As a part of the user selection board, the test facility would therefore give their opinion on eligibility of selected applicants if their infrastructure meet the requirements of the presented test programme.
Access procedure	As a first start, it is recommended to keep proper traceability of the agreement between test facility and selected applicant. This agreement will include the plan for the client to access the test site's facility, with inclusion of the expected start date and duration. The rest of the process should be based on the test sites own policy for accessing the infrastructure. The step and plan for installation will be the object of regular catch-up sessions and exchanges between client and testing lab/facility. The arrangement between both parties should cover: - Commissioning/decommissioning plan - Installation (See **Error! Reference source not found.** - Personnel mobilisation - Data handling (See 4.2.4, 4.2.5, 4.2.8) - Reporting
Post-Access obligations	Section 5 of D3.1b (Marinet2: Christophe Maisondieu & Alan Tassin, 2017) covers requirements indication for both parties after the end of the test period. It is recommended to have this item agreed before start of the test in the commissioning/decommissioning plan.

Post-Access Validation	The tester would make sure to validate that post access obligations have been met once the previous point has been fully fulfilled.
Travel & Subsistence Refund	Marinet2 provides a contribution of €1000 per User Group per week towards the travel and subsistence expenses of Users. The Test facility is in charge of administrating this refund and should make sure the costs have been reimbursed through the access provider procedure.

Table 8: Step by step procedure for transnational access

3.2 Developer questionnaire

The developer questionnaire is a recommended document specific to the test facility and written in accordance to the standard the infrastructure aims for. This document should be made available to future clients in order to capture the MEC main information prior to starting commissioning and installation.

The developer questionnaire should be put in place by test site operations management to gather the main information regarding the applicant and its MRE device. This questionnaire is intended to provide an oversight of the developer's objectives and the potential constraints linked to the tested prototype. The questionnaire should be filled by the client and reviewed by the test site prior to starting any commissioning work in the facility, it covers requirements of Technical feasibility assessment required in transnational access procedure.

3.2.1 General presentation

The developer questionnaire is intended to gather information for the test site, in order to evaluate the requirements specific to the developer and their device. Key information should therefore be addressed. The following list provides an informative set of data that test facilities should require from their client in order to assess the main parameters for integration and testing of the device.

1) Development stage of the device
    - What are the objectives of the client in terms of technology development (TRL, development stage, …)
2) Standards and guidance
    - Is there any specific guidance against which the client wants to build the test plan?
    - What previous steps have been undertaken by the client in compliance with this standard under test?
3) Testing support
    - Is there qualified personnel from client side with significant experience with the device?
    - Has the client submitted relevant documentation regarding the device:
        - CAD/technical drawings showing the device main dimensions and sub Components (For layout in the test)

    - Commissioning plan showing how the client will transport and install the device on site (Should be reviewed and agreed by the tester)

4) Physical spec of the device and test facility conditions
    - In the questionnaire, the test facility should require clear information regarding the device, which includes the scale, the physical properties, and the specifications in terms of installation. This requirement can usually be quickly covered by clear CAD or technical drawings of the device showing dimensions of the model to be tested at the facility.
      In general, it is recommended that the test site operations management require the format they find the most convenient in the questionnaire.

    - Any particular resource condition that the client wishes to observe during the test (In the parameters for a tank test facility, needs to be assessed prior to testing for an open site facility). Test facilities should make sure that the needs of the client have been properly listed and considered.

5) Instrumentation and data requirements
    - Has the client mentioned any specific item on instrumentation that the test facility should provide ?

6) Model installation/integration and operations
    - Are there some specific aspects for mooring/marine foundations that need to be considered? Has the client submitted them ?
    - Have the commissioning and assembly operations on site been clearly defined and agreed by all parties (See item 3) ?
    - Is the device control system able to be integrated in the facility/lab one? Has the client provided sufficient explanation on this item ?
    - Have these operations been considered in the test schedule?

These items are, once again, informative, but should be asked by the test facility in the questionnaire submitted to the client in order to get a proper overview of the test/device requirements.

4. Testing and technology assessment method

There is a wide variety of ways to capture marine energies depending on which category developers focus on (Tidal, wave, wind, …), and what strategy is adopted for the energy absorption. The testing and technology improvement of a particular marine energy device necessitates a clear understanding of the scientific concept behind the energy absorption. The current industrial standards aim at identifying the common traits and performance parameters to allow assessment of this performance capability and, the IEC committee has been able to list these parameters that developers need to include in their development plan. However, each technology still needs to follow a clear depiction of scientific methods behind their concept to prove its reliability. A stated in (Marinet2: Christophe Maisondieu & Alan Tassin, 2017), TC 114 currently addresses the following points:

- Management plan for technology and project development
- System definitions
- Performance measurements of wave, tidal and water current energy converters
- Resource assessment requirements
- Design and safety including reliability and survivability
- Deployment, operation, maintenance and retrieval
- Commissioning and decommissioning
- Electrical interface, including array integration and / or grid integration
- Testing: laboratory, manufacturing and factory acceptance
- Measurement methodologies of physical parameters of the device

This section addresses and provides guidelines for test facilities on how to handle and assess these items as provided by the clients.

In general, the power performance assessment process of marine energy devices should be properly streamlined by testing facilities in a way that is compliant with their internal policy, and the applicable standard. The figure below provides a high level structured overview on how this kind of process should be organised.

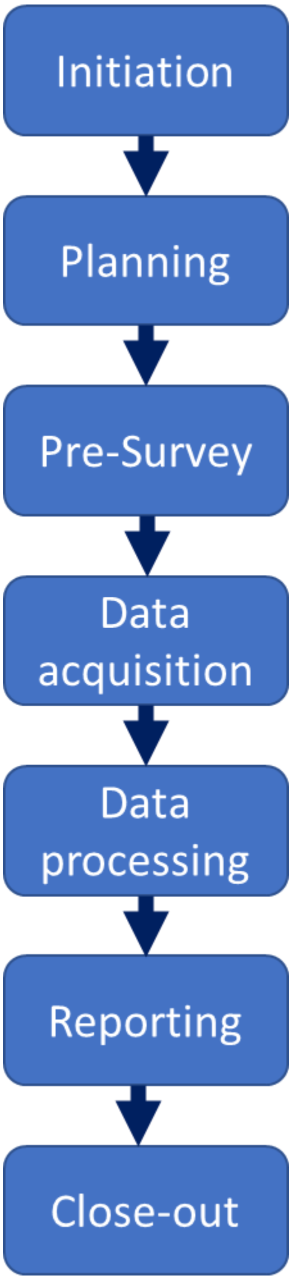

Figure 2: Process flow for power performance assessment of marine energy devices

4.1 Marine energy converter information

Assessment of a device performance focuses on a comparison between incoming resource and produced energy output, but also requires consideration of the device specific parameters. The energy capture capacity of a MEC is often a function of its geometry, and its installation layout. As a result, a clear understanding of these items is necessary to undertake an accurate test of the device.

Recommendations on how testing bodies should require information regarding device integration and high level objectives of the test are listed in section 2) of this document. The purpose of this section is to list the primary technical parameters required for a proper device testing, as specified in industry standards.

4.1.1 MEC dimensions and physical parameters

The MEC dimensions are needed to establish its energy capture performances against the input resource. The wide range of MEC physical characteristics and structures makes it difficult to standardize what parameter should be used to assess the device's overall dimension.

The IEC documentation provides

Category	**Primary physical parameter**
Tidal	- Equivalent diameter - Distance from seabed/surface to hub - Capture area
Wind	- Equivalent diameter - Height of hub from surface - Capture area
Wave	- Capture length (Non geometrical) Note: *The calculation of the WEC performance as per required in IEC technical specifications is currently based on input resource and output electricity production from which the capture length is deduced. This calculation is made without accounting geometry of the device.*

Table 9: Geometric parameters of MEC used for performance assessment

As mentioned below, it is, however, possible that additional parameters might be considered with the ones required by industry standard.

Category	**Primary physical parameter**
Performance parameter based on MEC geometry	Depending on the proof of concept provided by client, it might be clear or not which parameters in the MEC geometry intervene in the theoretical energy output calculation. Prior to starting the test design, test facilities should make sure that all parameters linked directly to the MEC geometry are properly listed and accounted in the plan (Appropriate sensors included in the instrument package if necessary)
Performance parameters based on MEC installation site	Depending on configuration of the MEC, the analytical model might vary directly with constraints of the test site

	(eg: is the power output a function of the depth installation or mooring configuration?). Not only these parameters should be considered in the test, but facility owners should make sure that this aspect has been considered by the client in the device development strategy, and that the test design is produced accordingly.
Performance parameters based on MEC operating mode	This item will be developed in 4.1.2 and is mostly focused on high TRL systems, but it is important that a clear description, or estimation of the device normal operating mode is provided by the client (Is there any resource parameter above/below which integrity of the device or output quality is not guaranteed anymore). A required listing of operating signals and formats should be provided by the client.

Table 10: Informative list of additional technical parameters

4.1.2 Operating mode

The performance assessment of a MEC focuses on energy produced during its normal operating mode. Depending on the TRL of the device, the standard might require the operating status of the device to be monitored. The operating mode should be verifiable using one or several sensors outputs agreed between the client and the test facility and which should display the status of the MEC in a certain way.

IEC technical specifications for power performance assessments ((International Electrotechnical Commission, 2005), (International electrotechnical commission, 2012), (International electrotechnical commission, 2013) provide requirements on how the operational mode of the device should be monitored.

In general, for a proper assessment of the device availability, a test log monitoring method should be agreed between test facility and client in way that suits both the device specificities and the infrastructure requirements. Prior to starting the measurement campaign, both parties would ensure that the log is adapted to the test output requirements and that the resulting file can be used accordingly for availability assessment.

4.1.3 Integration

The integration of a marine energy device to a given test infrastructure/lab is widely specific to the structure itself and needs to be studied in detail before engaging any commissioning work. As a specific aspect, there is no clear standard or industry guideline that includes the instructions for a proper device integration. Depending on the nature of the test facility, these instructions can be changing quite a lot from one infrastructure to another.

The main items generally covered regarding the device integration are displayed below:

- Connection of the device to the Digital Acquisition (DAQ) system of the lab
- Connection of the device to the electrical measurement installation, compliance with the corresponding standard
- Accurate commissioning of the device with appropriate mooring/marine foundation in order to ensure the device's survivability during the test
- Commissioning plan, including risk assessment of the process

Depending on the size/environment of the labs, the requirements change and depends more or less on the device itself. The table below provides a list of international standards and guidance covering the items listed above. This list is provided as information and might not be taken fully in account by the test facilities depending on their internal process.

Item	Requirement/standard
Data acquisition	**Wave basin** IEC TS 62600-103: Wave, tidal and other water current converters. Guidelines for the early stage development of wave energy converters. Best practices and recommended procedures for the testing of pre-prototype devices, section 8 (International Electrotechnical Commission, 2018) **Tidal Basin** IEC TS 62600-202 (Draft) (International electrotechnical commission) Deliverable 4.1-1: Common Marinet2 standard testing and benchmarking plan (Tidal Energy) (Marinet2: S Ordonez Sanchez, 2019) Equimar Deliverable 3.1: entitled "Identification of Limitations of the Current Practices Adopted for Early Stage Tidal Device Assessment" (Equimar: J.A. Clarke, 2009) **Wave field test facilities** IEC TS 62600-100: Wave, tidal and other water current converters. Electricity producing wave energy converters. Power performance assessment, sections 6, 7, 8 (International electrotechnical commission, 2012) **Tidal test facilities** IEC TS 62600-200: Wave, tidal and other water current converters. Electricity producing tidal energy converters. Power performance assessment, sections 7.3 and 8 (International electrotechnical commission, 2013)

Electrical installation	It is recommended that test facility follows the below technical specification foe integration of devices on their test site: IEC TS 62600-30: Marine energy. Wave, tidal and other water current converters. Electrical power quality requirements (International Electrotechnical commission, 2018) Work package 4.3 of Marinet also intended to deliver guidelines on grid integration of MEC given their specificities and the country of installation, which resulted in Marinet deliverable 4.3 (Marinet: Giebhardt, Kracht, Giebhardt, Dick, & Salcedo, 2014) It has to be noted that the previous Marinet programme also resulted in a benchmarking deliverable regarding grid specificities in Europe under work package 2.26: (Marinet: Endegnanew, et al., 2013).
Commissioning, decommissioning	The rules for commissioning and decommissioning should be agreed by both developer and test facility and comply with local rules for sea operation security (Open field sites)
Mooring/Marine foundation (Or scaled models for basin/tank tests)	Current IEC rules for mooring system design of MECs are stated in IEC TS 62600-10: Marine energy. Wave, tidal and other water current converters. Assessment of mooring system for marine energy converters (MECs) (International Electrotechnical Commission, 2015) The Marinet programme also delivered a review of mooring testing systems for MECs under work package 2.21: (Marinet: Johanning, Thies, & Weller, 2014). This item is important in order to assess suitability of the installation for the intended mooring system.
Resource assessment (Field test facilities)	**Wave** IEC TS 62600-101: Marine energy. Wave, tidal and other water current converters. Wave energy resource assessment and characterization (International electrotechnical commission, 2015) IEC TS 62600-102: Marine energy. Wave, tidal and other water current converters. Wave energy converter power performance

	assessment at a second location using measured assessment data (International electrotechnical commission, 2016) **Tidal** IEC TS 62600-201: Marine energy. Wave, tidal and other water current converters. Tidal energy resource assessment and characterization (International Electrotechnical Commission, 2015) **Wave and tidal** Equimar deliverable 2.7 Protocols for wave and tidal resource assessment (Equimar: Davey, et al., 2010) **Wind** Marinet deliverable 4.16 Report on options for full scale wind resource surveying (Marinet: Courtney, et al., 2014)

Table 11: Industry standards based on integration of the device on site

4.1.4 Resource assessment and conversion strategy

The resource assessment for marine energy devices is now standardized for the three main categories presented in this document that are wave, wind and tidal. The IEC committee has published guidelines and technical specifications that can be used by test facilities, particularly open sea sites, to perform their site characterisation and present the input resource they are expecting.

Specific aspects of some marine energy devices might require, however, an extension of the resource assessment depending on the category it belongs to. The wide range of MEC structure can make the resource characterisation different depending on how the MEC converts the input resource energy. It is therefore, important that test facilities check with the developer that their strategy for energy capture is properly described, and compliant with what the selected facility allows.

The IEC TS for early stages wave energy devices (International Electrotechnical Commission, 2018) requires, for example, the presentation of a mathematical model as a proof of concept of the device depending on the development stage. This strategy acts only as an example but is, in itself, a way to assess efficiently and clearly the resource conversion method of a particular MEC.

4.1.5 Measurement methodologies

This section gives a high-level review of the points described in section 6. In general, it is expected that the measured quantities are based on outcomes of the device performance in terms of energy production and behaviour at sea (Survivability, mooring loads, …).

The first item to be checked and confirmed with the client, is that the instrumentation used on site fulfils the requirements of the testing strategy by recording the appropriate parameters. This is the reason why the previous point 4.1.4 needs to be clearly agreed between both parties. The instrumentation set-up is part of the design of experiment as mentioned in 4.2.1 and needs to be clearly stated prior to starting the test.

In general, instrumentation should be properly calibrated and subject to a suited maintenance strategy, as well as operated by qualified personnel members. The list below provides the standards and guidelines may be used by test facilities to meet requirements of the industry for a proper instrument handling strategy.

- ISO/IEC 17025:2005 General requirements for the competence of testing and calibration laboratories.
- ISO/IEC 17020:2012 Conformity assessment -- Requirements for the operation of various types of bodies performing inspection.
- ISO 9001:2015 Quality management systems — Requirements.

It is suggested that internal strategies put in place by test facilities that comply with their specific policy fulfils these requirements.

4.2 Testing methods

Given the diversity in test facilities and MEC designs, producing a single methodology for each TRL/MEC category is impossible, and current industry standards can only be provided as a set of requirements that test facilities need to fulfil to validate the test.

However, the past projects and development programs have enabled discoveries on how these requirements could be observed in a suitable way for both test facility and developer.

4.2.1 Design of experiment

The design of experiment describes the test layout in terms of instrumentation and set-up (Test steps and objectives). The design should be produced prior to starting the test and be agreed by both the tester and the client.

The table below provides an indicative set of requirements for each item of the test design, the approach might be different for each tester considering the internal policy of lab/facilities but it gives an overview of what should be included in the design documentation.

Item	Recommendation

Instrumentation layout	The instrumentation layout includes the list of devices used in the testing campaign as well as their arrangement in the overall installation set-up. For each development stage and MEC category, it is recommended that a diagram showing location/area of the MEC in the testing facility is provided. The diagram should show the set of instruments used during the test and their disposition/location in the facility. In general, a list of the instruments used for the test should be included in the test design. The list should include at least: - Role of the instrument in the testing process - Manufacturer and serial number - Any relevant information regarding calibration of the sensor; such as a calibration certificate.
Test set up	The test set up should be properly divided in the several steps with their objectives accurately described. Given the TRL category and the nature of the site, the set-up of the test might change regarding whether or not the resource input parameters can be monitored. Tank test facilities would, for example, provide the list of sea-states/current speeds expected to be covered during the test. In general, the test set up would include the following: - Expected duration of the test - Comparison with requirements of the corresponding development stage gate - (Tank testing only) Expected resource input set-ups and duration for each of them

Table 12: Recommendations for design of experiment

4.2.2 Calibration of sensors

All IEC technical specifications recommend the calibration of the test instruments to be carried out by a ISO 17025 accredited body (International Organization for Standardization/International Electrotechnical Commission, 2017). However, some specific aspects of the sensors might require a dedicated process which may not be clearly defined in the international procedures and guidelines.

4.2.3 Experiments on rare or extreme events

The test facilities should have a procedure in place for handling a deviation from the standards without threatening integrity of the test. The process documentation should include a step by step procedure and an assumption of the deviations that could occur considering specificities of the facility (Types, expected failure, …).

No specific guidance exists on how these events should be handled. However, the general approach recommends definition of limit states for availability of the MEC and its system. A high level guidance for limit states of MEC mooring components is provided in IEC TS 62600-10 (International Electrotechnical Commission, 2015) and gives an overview of how these parameters should be used.

4.2.4 Documentation of tests

Each testing body may have its own internal policy for recording and documenting tests in their facility, this section provides a high-level guideline on what aspects should be covered to comply with the standards. The aspects covered in this section are detailed in a deeper way in section 7 of this document.

Item	Recommendation
Test plan	The plan describes the parties involved in the test, what are the milestones and deliverables, and how the parties expect to deliver the testing campaign and its deliverables. Additional information might have to be provided depending on the TRL and MEC category the test addresses to.
Test design	The test design includes layout of the sensors package used during the test, as well as information about the device integration, and the electrical/monitoring installation. The test design also lists the test set-ups and a structured description of the different steps and phases that will be observed by the tester during the campaign.
Test report	The test report synthetizes the points above and in addition provides the results of the test as required by the applicable standard. Some technical specifications or standardised guidelines may provide an example and a structure template of how the report should be presented, but this statement is not applicable for all of them. In general, test facilities would make sure that each section of the documentation is addressed in the report and that all outputs required in it has been produced accordingly using the test data.

Table 13: Informative typical test deliverables

4.2.5 Quality and accuracy of results

Depending on sensor outputs, a general statement on what QC methods to apply to output data is difficult, however, test facilities may have their own process in place for application of QC methods to the data recorded during testing campaigns.

In general, it is recommended that the QC process applied on the test data is recorded and substantiated in the report.

If the results are recorded using a software or record tool developed by the testing facility, it should be made sure that this tool is properly validated with records of the process kept up to date.

4.2.6 Uncertainty analysis and quality assurance

The uncertainty analysis should be the object of a dedicated study by the test facility and the client since it is truly specific to the test layout and instruments used for measurement. In general, it is assumed that calculation of measurement and results uncertainty should be handled by qualified personnel members.

Section 5.3 of this document provides a list of applicable standards and guidelines for uncertainty of measurements. This list is extendable and might be completed by specific guidelines used by test facilities for assessment of uncertainty in their testing campaigns.

4.2.7 Quality of prototype models

This section mostly refers to the early stages development of MECs, particularly tank or dry testing in which the use of small-scale device raises the concern of the similitudes with the expected real-scale converter.

4.2.8 Data storage

The data storage is truly specific to the facility owners and their policy in terms of confidentiality/storage, it is therefore not guaranteed that the methods provided in this section are applicable to all test infrastructures. The items listed below however, constitute recommendations that should be included in the data storage policy of Marinet2 partners.

The table below provides the recommendations for each item regarding data storage that have been acquired after the testing programmes undertaken during Marinet2:

Item	Recommendation
Back up storage	In case of failure/destruction of the test output storage system, the tester would make sure that a back-up facility is available and with sufficient storage to retrieve the data recorded during the test. The tester would make sure that enough space is available considering the estimation of the amount of data to be recorded.
File referencing	Each tester has its own method for assessing traceability and identification of the datasets. However, it is recommended to verify that the referencing method allows the output files and the time/day they were produced to be uniquely identified.
Traceability	This item constitutes an addition to the previous point regarding file identification. Depending on the test plan, the number of sensors can increase significantly from one test to another. It is recommended that the output file name from each sensor includes a reference allowing to the instrument that generated it to be identified directly (Serial number, for example)

Table 14: Data storage informative requirements

The table below provides a set of existing recommendation documents for appropriate storage of test data. This list is, once again, informative and aims to help test facilities to make sure their storage policy is compliant with their specific needs, the industrial recommendations, and the client's benefits.

Item	Recommendation
Wave data	Marinet deliverable 2.9: Standards for Wave Data Analysis, Archival and Presentation (Marinet: Finn, Dampney, Lawrence, Margheritini, & Cândido, 2015) Marinet deliverable 2.14 Wave data presentation and storage review (Marinet:Davide, et al., 2012)
Tidal data	Marinet deliverable 2.18: Tidal data analysis best practice (Marinet: A. Grant, T. McCombes, C.M. Johnstone, 2012)

Table 15: Data handling guidelines

5. Tank testing activities common practices

Even using an apparently identical test layout, it is not guaranteed that a particular testing campaign could produce the same results between two occurrences of a same setup. Repeatability of a particular test layout is one of the points studied in the Marinet2 programme, it is essential to be able to expect the same results between two repetition of the same test in order to confirm precision of the method. Purpose of Marinet2 work package 4 was therefore, to identify which parameters linked to the infrastructure can influence the outcomes of the campaign and change the results from one facility to another, in order to minimise differences in outputs of a same test set-up between two infrastructures.

5.1 Round Robin

A Round Robin testing campaign was undertaken as a part of Marinet2 work package 4 for both wave and tidal technologies. The objective was to use a same MRE technology in different facilities participating in Marinet2 program in order to identify what items did influence the outcomes of the test from one infrastructure to another. General test plan of tidal round robin is presented in (Marinet2: S Ordonez Sanchez, 2019).

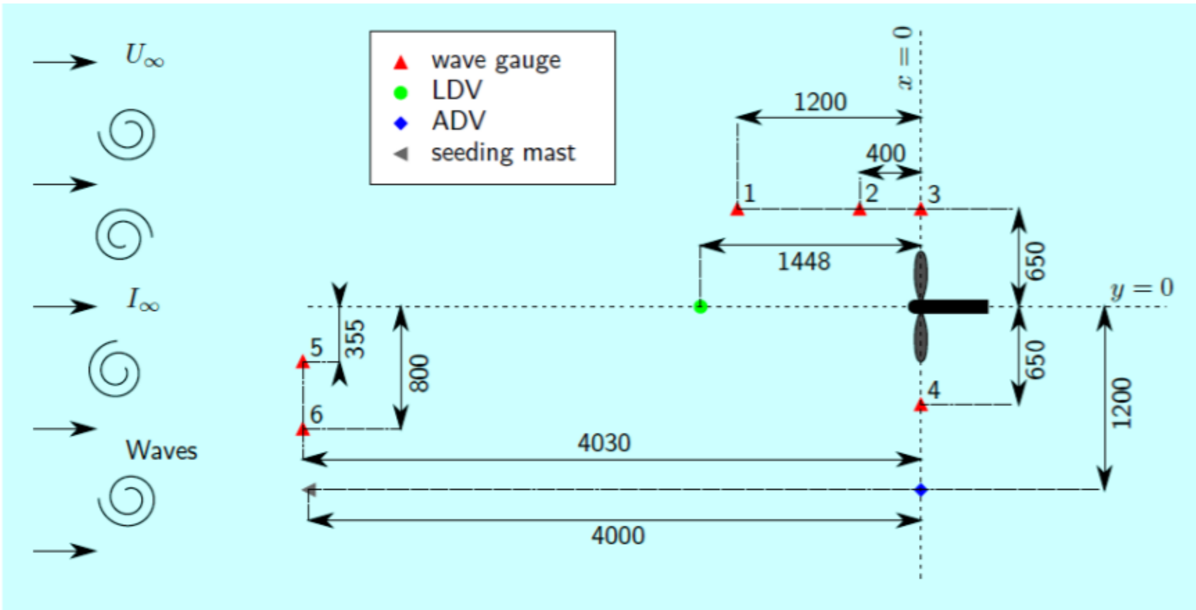

Figure 16: Tidal Round Robin layout

5.2 Instrumentation

This section focuses on the instruments sets that were used in Round Robin testing campaigns. Purpose is to list the recommendations that were learnt from the work package's outcomes in order to apply them for similar layouts.

The recommendations presented in the table below are taken from (Marinet2: S Ordonez Sanchez, 2019) and might be upgraded in the future with incoming outputs of the Round Robin testing campaigns.

Sensor	Observation/Mitigation
Wave probes/probes	**Observation** Daily calibration to mitigate sensitivity to temperature might be necessary for wave probes, other sensor will need to be calibrated by qualified personnel members in accordance to ISO/IEC standard 17025 prior to testing. (International Organization for Standardization/International Electrotechnical Commission, 2017) **Mitigation/method** Moving the gauges to five known positions on their mounting system and recording the voltage output
Acoustic Doppler Velocimeter (ADV)	**Observation** Appropriate mounting system might be required for the sensor. **Mitigation/method** The recommended mounting method inherited from the Round Robin layout is provided in section 2.4.3 of (Marinet2: S Ordonez Sanchez, 2019).
Laser Doppler Velocimeter (LDV)	**Observation** Delicate transport operation inducing useability of the device in only one facility. **Mitigation/method** Use of the ADV as a replacement.

Table 17: Suggested common practices for measure instruments in tidal Round Robin testing

5.3 Measurement uncertainty

This section is general and does not regard only the outcomes of the Round Robin testing campaigns. Uncertainties of measurement can be induced by various factors including the sensors, measure instruments and the test facility's specificities. Since each test design is unique, the performance assessment technical specifications provide a general statement of which uncertainty contributions should be considered in the test design.

ISO/IEC International guidelines and standards regarding the handling and calculation of uncertainties are provided in the table below as well as resulting deliverables from previous projects. Depending on the technical specification used by the tester, they should make sure that the uncertainty calculation process has been produced in accordance to the method outlined in it.

Standards for estimation of uncertainty of measurements

ISO/IEC	ISO/IEC GUIDE 98-1:2009 Uncertainty of measurement — Part 1: Introduction to the expression of uncertainty in measurement (International Organization for Standardization/International Electrotechnical Commission, 2009)
ISO/IEC	ISO/IEC GUIDE 98-3:2008: Guide to the expression of uncertainty in measurement (International Organization for Standardization/International Electrotechnical Commission, 2008)
ITTC	Procedure 7.5-02-07-03.15 – Uncertainty Analysis – Example for horizontal Axis turbines Procedure 7.5-01-03-01 – Uncertainty Analysis, Instrument Calibration
Equimar	Deliverable 4.2: Data Analysis & Presentation to Quantify Uncertainty

Table 18: Uncertainty of measurement reference documentation

6. Measuring results

6.1 Instrumentation

6.1.1 Calibration

This section describes a list of items and recommended guidelines for calibration of the instruments and facility (If applicable, eg tank testing) prior to commencing the test. The objective is to optimise the process put in place by testing bodies to make sure that instruments used in testing campaigns are suited for their intended purpose.

In general, most facilities and testing infrastructures may have their own process in place for calibration of their instruments. The objective is not here to develop the calibration process for each kind of instrument but to provide references and guidelines for test facilities to build the appropriate process considering their instruments package.

It is recommended that test facilities produce their own documentation, compliant with the industry standards and their facility's specificities, the calibration documentation should include the following points:

1) General process to confirm that all sensors and measure instruments have been calibrated in compliance with required industry standard (Learnt from previous work package)
2) A high-level step-by-step procedure for making sure that the instruments are calibrated and ready for the test
3) The method used by the tester to prove traceability of the calibration process/documentation

Test facilities should keep in mind that the calibration should be carried out by qualified personnel members, the table below provides the list of the standards applicable to the calibration process and on which test facilities should rely for setting up their instruments' calibration process.

Standard reference	Application
ISO/IEC 17025:2005	General requirements for the competence of testing and calibration laboratories
ISO/IEC 17020:2012	Conformity assessment -- Requirements for the operation of various types of bodies performing inspection
ISO 9001:2015	Quality management systems — Requirements

Table 19: Testing bodies requirements documentation

The experience of test facilities on specific MRE testing campaigns is valuable to gather guidelines and recommendations for calibration of the instruments. The table below reports on observations made regarding this item on previous or current research projects on MRE development.

Category	Documentation

Tank testing	Marinet deliverable 4.01EC: Tank test related instrumentation and best practice (Marinet: Ohana & Bourdier, 2014) Equimar deliverable D3.4 Best practice for tank testing of small marine energy devices (Marinet: McCombes, et al., 2010)
Field testing	Marinet deliverable 2.5 EC: Report on Instrumentation Best Practice (Marinet: Têtu, et al., 2013)

Table 20: Existing guidelines for MECs testing instruments calibration

6.1.2 Software validation

Processing of the test data in accordance with the requirements of the standard documentation used by the tester might require use of an appropriate software/tool. This software might be internally developed by the tester, in which case, application of a proper validation process is recommended to ensure suitability of the tool for its intended purpose.

This section regards validation of software tools developed internally by test facilities. These tools can follow different purposes (Generation of the outputs, data collection and quality control…) and should be validated in accordance. The Laboratory should perform validation before using it for the first time and subsequently according to criteria defined in the corresponding specific procedures. This validation will consist of verifying that the values obtained by means of this internal software and manually give the same results.

Traceability of the validation process must be kept and updated regularly, the software tools are considered as part of the equipment and should therefore, be the object of a careful maintenance and be handled by qualified personnel members.

To get back to the validation aspect, validation of the tool should be reported, with display of the expected results calculated manually, and the ones calculated by the tool for a particular input. The table below provides guideline on the validation and traceability assessment process that should be kept up to date by test facilities.

Item	**Description**
Software validation process	The validation of the software is the first task to fulfil once the software tool is complete. It should be demonstrated appropriately that the software calculates the appropriate result for a given input. It may be assumed that validation phase of software follows the same purpose as calibration of measurement instruments, using a known input and comparing the calculation results with the ones that are expected.
Software validation report	The results of the software validation process should be accurately reported in a referenced document. This report should be updated if necessary, in case of significant

	adding/modification of the software, with the outcome of the related validation process.
Software modification	Each modification/adding of the software should be recorded and registered. The record should include the name of the developer, the object of the modification, and its date. For more convenience, it is recommended to use a versioning software agreed by member of the test team working on the software development. The following shows an informative list of versioning tools that could be used for software traceability: - GIT - Mercurial - Subversion - … The versioning software should be agreed by members of the team working on software development. It is also recommended that the tester put in place its own documentation for version control of internally developed tools.
Software access	As mentioned above, depending on the outputs required by the technical specification/documentation the tester refers to, a software dedicated to processing the test data accordingly might be needed. This software may be developed internally by the lab owner (Which would require getting through the validation process described above), or might be provided by a subcontractor, in which case, both parties should agree on the relevant intellectual property to guarantee confidentiality of the data/tools exchanged in the process.

Table 21: Internal software validation and traceability

6.1.3 Maintenance

This section constitutes a continuation of section 5.1.3 of D2.3 (Marinet: Eider Robles, 2018), these recommendations focus on experiences stated by testing partners of Marinet2 and are provided for an informative purpose. The wide range of equipment used during the testing campaigns makes it difficult to produce a general statement on how maintenance of equipment should be handled. However, this section intends to formulate how failure could be prevented by performing a regular check-ups of equipment before, during and after use.

For all pieces of equipment owned and used by test facilities, it is recommended that a clear formulation of instructions on the following items would be made available to everyone:

Item	**Description**

Instructions for use, conservation, and storage	Each testing body may have its own internal policy on how instruments and equipment should be handled and stored. It is, however, expected that the equipment manufacturer will provide their own set of recommendations on this item. Test facilities should make sure that documentation for a particular piece of equipment is properly referenced and can be found by personnel members quickly and easily. A asset management database is fundamental for the use of test equipment.

Table 22: Equipment storage methods recommendation

The types of maintenance that are considered are:

Item	**Description**
Preventive maintenance	The list of equipment used during the test is normally included in the test design. For each of the items in it, a maintenance process should be in place based on the device's specificities. Prior to testing, the tester should make sure that the maintenance process is up to date with the equipment's manufacturer requirements. Preventive maintenance is based on a regular check of the instruments/equipment conditions. For the items for which it is necessary, it is recommended that a checklist like process is set up by the tester to complete preventive maintenance. The maintenance process may come from the device's manufacturer itself. It is assumed that the maintenance will be performed by a qualified team member. Maintenance of the test equipment is under the test facility responsibility, however, the maintenance process for the MEC should come from the developer and be agreed by both parties prior to starting the test.
Scheduled maintenance	The internal maintenance process is based on the test team experience and qualification. The personnel involved in maintenance of one particular piece of equipment should be sufficiently qualified and have proof of the corresponding training/competency if needed.

	Test facilities should make sure proof of their personnel qualification for instrument maintenance is available. Based on specificities of the equipment, it might be necessary to submit equipment to a qualified external body for performing maintenance procedures (eg: calibration of instrument carried out by a suitable 17025 accredited body). The pieces of equipment for which an external maintenance process is necessary should be properly listed and the corresponding maintenance process specified. Regular contact with the external body in charge of maintenance should be made by the tester to make sure that the process still follows the manufacturer requirements.
Corrective maintenance	Corrective maintenance is assumed to occur after failure of the device or piece of equipment. The plan for corrective maintenance should include at least: - Appropriate list of spare items/components for replacement in case of failure - Appropriate plan for reparation and replacement of test equipment
Instructions for use, conservation, and storage	Each testing body may have its internal policy on how instruments and equipment should be handled and stored. It is, however, expected that the equipment manufacturer provides their own set of recommendations on this item. Test facilities should make sure that documentation for a particular piece of equipment is properly referenced and can be found by personnel members quickly and easily. The use of an overall asset management system would include a list of spares for test equipment.

Table 23: Categories of maintenance and corresponding instructions

In addition to these points or in order to complete them, this section would specify any high-level maintenance program agreed by Marinet2 partners for the above points.

6.2 Observing results

6.2.1 Traceability of the data

Traceability of the data is one of the main requirements regarding the test outcomes quality insurance. Recommendations are provided in 4.2.8 for referencing of the test outputs to make sure each test results and their corresponding generation process can be properly listed.

In general, traceability aims at proving that the results of the test have been produced by a proper process handled by qualified people. Records of the information linked to their calculation is therefore needed to validate this item.

6.2.2 Similitudes and models

Depending on the TRL and facility used for the test, the MEC structure used in the test might present a reduced scale factor that needs to be taken in account when exploiting the results for technology development. IEC technical specifications 62600-103 and 62600-202(Draft) requires that similitude for the MEC components and general physical behaviour of the device are properly listed and justified using the suitable scientific method. A scaling method of the results and geometrical parameters of the MEC might need to be applied such as Froude similitude as provided below.

Physical parameter	**Froude scale**	**Unit**
Length	λ	m
Time	$\sqrt{\lambda}$	s
Structural mass	λ^3	kg
Inertia	λ^5	
Force	λ^3	N
Torque	λ^4	Nm
Linear velocity	$\sqrt{\lambda}$	m/s
Angular velocity	$1/\sqrt{\lambda}$	s-1
Linear acceleration	1	m/s^2
Angular acceleration	$1/\lambda$	s^{-2}
Pressure	λ	Pa
Power	$\lambda^{3.5}$	W

Table 24: Scaled reference physical parameters (Froude method)

A reduced scale test needs therefore a similitude/modelling section agreed by both the test facility and the client to verify that both structural and resource parameters can be considered accurately by the test design.

7. Reporting

After the access, the User Group Leader must write a project report to disseminate the foreground (information and results) that they have generated under the project in order to progress the state-of-the-art of the sector. The purpose of the report is to highlight the scientific output of the access received (considering confidentiality arrangements as explained in the Rules).

The reporting of a test must follow the requirements of the standards/guidelines it relates to. Test facilities may, however, have their own internal policy and process for reporting while staying compliant with the guidelines. This section is not intended to provide a centralised reporting method for all Marinet2 partners, but to list the items that should be covered in the reporting session.

Item	**Instructions**
Presentation of the device	The device/prototype needs to be correctly described, if possible, using technical drawings/pictures, to see roles of sub-components. This part of the report would include high-level technical parameters of the MEC as provided by the client to the tester. The concept of the MEC should also be properly described to justify the use of the facility and the recorded physical parameters.
Presentation of the test facility	The facility/lab, should be presented accurately with the corresponding characterisation based on the standard requirements (e.g: Basin calibration for tank test, site characterisation for open sea testing,…). A general layout of the test site including expected location of the MEC/prototype as scheduled in the test plan should be included.
Presentation of the test objectives	The test objectives should include TRL level of the device before the test and what stage gates the developer intends to fulfil.
Presentation of the test design/layout	The test layout includes the instrumentation package and installation schemes as well as the different test set-ups that will be observed during the testing campaign.
Test plan	The test plan provides the milestones and expected deliverables of the test. It is also expected that the plan section describes how the process will follow steps of the test design. At a minimum, it is recommended that the test plan includes the following items: - Main objectives and context of the test, including presentation of the device, the test facility and the development stage - Resource/environment specifications (Characterisation for open sea testing, tabulated environmental conditions for tank test facilities) - Instrumentation with calibration records if needed

	- General layout of the test - Personnel in charge - Expected timings and set-up for each step
Log assessing completion of the test plan during and after the test	The developer would keep a log of the different test set ups and how they were performed. It is recommended that a record of failures/unexpected events is kept and correctly reported in the final document. The tester should also detail how these events impacted outcomes of the testing campaign.
Presentation of test results	The results of the test would be presented in a dedicated section and should be based on requirements of the standard/guidelines followed by the test.
Conclusion	The test facility would agree with the developer whether or not objectives of the test were fulfilled. Any significant item missing at the end of the test should be included in the report. Any lessons learnt from the test should also be noted by both parties and deduce how they could improve future testing processes.

Table 25: Common reporting items as identified in testing industry standards

Appendix 1

Technology Readiness Levels

Level	Summary
1	Basic Principles Observed and Reported
2	Technology concept and/or application formulated
3	Analytical and experimental critical function and/or characteristic proof of concept
4	Component/subsystem validation in laboratory environment
5	System/subsystem/component validation in relevant environment
6	System/subsystem model or prototyping demonstration in a relevant end-to-end environment
7	System prototyping demonstration in an operational environment
8	Actual system completed and qualified through test and demonstration in an operational environment
9	Actual system proven through successful operations

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