IEC TS 62600-103

Edition 2.0 2024-07

TECHNICAL SPECIFICATION

colour inside

Marine energy – Wave, tidal and other water current converters – Part 103: Guidelines for the early stage development of wave energy converters – Best practices and recommended procedures for the testing of pre-prototype devices

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Part 103: Guidelines for the early stage development of wave energy converters – Best practices and recommended procedures for the testing of pre-prototype devices

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IEC TS 62600-103 has been prepared by IEC technical committee 114: Marine energy – Wave, tidal and other water current converters. It is a Technical Specification.

This second edition cancels and replaces the first edition published in 2018. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) Revised several numeric values (e.g. test durations) to align with best testing practice;
b) Introduced guidance and requirements relating to PTO testing and closed-loop control;

c) Introduced uncertainty clause in normative part of the document;

d) Strengthened the document sections relating to Stage 3, the first sea trials;

e) Updated the data synchronisation requirements to align with best testing practices.

The text of this Technical Specification is based on the following documents:

Draft	Report on voting
114/510/DTS	114/523/RVDTS

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this Technical Specification is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

A list of all parts in the IEC 62600 series, published under the general title *Marine energy – Wave, tidal and other water current converters*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

IMPORTANT – The "colour inside" logo on the cover page of this document indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

Developing wave energy converters (WECs) will always be a demanding engineering process. It is important, therefore, to follow a design path that will minimise the risks encountered along a route of increasing technical complexity and fiscal commitment. This document presents a guide that addresses these issues, the approach being based on a proven methodology adapted from other technology areas, especially NASA and similar heavy maritime engineering industries.

The scope of the work is defined in Clause 1. Normative references and definitions of important terms are introduced in Clause 2 and Clause 3 respectively. The core of the document then follows a twin-track approach, relying on:

a) a structured or staged development approach outlined in Clause 4, and

b) a set of model specific and goal orientated clauses (Clause 9 to Clause 11) ensuring that targets are clearly defined and attained with confidence. Testing specific requirements such as test planning (Clause 5), reporting and presentation (Clause 6), characterisation of the surrounding wave environment (Clause 7), data acquisition and real-time control (Clause 8), and testing uncertainty Clause 12 are also included.

The structured development schedule makes use of the ability to accurately scale wave energy converters such that sub-prototype size physical models can be used to investigate the relevant device parameters and design variables at an appropriate dimension and associated budget.

The parallel development of mathematical models describing a wave energy converter's behaviour and performance is encouraged, but the procedure is not included in the document.

This document is quite exacting in terms of both the approach and requirements for the development of wave energy converters since it takes a professional approach to the process.

An essential element for any published Technical Specification or International Standard is to allow an opportunity to provide feedback on its contents to the appropriate TC 114 Working Group. TC 114 utilizes a standard methodology to allow this.

To submit feedback such as proposed changes, corrections and/or improvements to this document, please send an email to the TC 114 Chair using the Contact TC 114 Officers feature on the IEC TC 114 Dashboard, accessible at www.iec.ch/tc114. On the right side of the Dashboard under Further information select the link to contact the TC 114 Officers. On the subsequent page find and select the Send Email link for the Chair to access the email tool.

Complete all the required elements within the email pop-up. For the Subject field please include the document title and edition you are providing feedback for (ex: feedback for TS 62600-1 ED2). In the Message field, include text which summarizes your feedback and note if further information can be made available (note attachments are not allowed). The Chair may request added information as needed before forwarding the submission to the remaining TC 114 Officers for review and then to the appropriate Working Group for their consideration.

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

Part 103: Guidelines for the early stage development of wave energy converters – Best practices and recommended procedures for the testing of pre-prototype devices

1 Scope

This part of IEC TS 62600 is concerned with the sub-prototype scale development of wave energy converters (WECs). It includes wave tank test programmes, where wave conditions are controlled so they can be scheduled, and first sea trials, where sea states occur naturally and the programmes are adjusted and flexible to accommodate the conditions. Commercial-scale prototype tests are not covered in this document.

This document prescribes the minimum test programmes that form the basis of a structured technology development schedule. For each testing campaign, the prerequisites, goals and minimum test plans are specified. This document addresses:

- Planning an experimental programme, including a design statement, technical drawings, facility selection, site data and other inputs as specified in Clause 5.
- Device characterisation, including the physical device model, PTO components and mooring arrangements where appropriate.
- Environment characterisation, concerning either the tank testing facility or the sea deployment site, depending on the stage of development.
- Specification of specific test goals, including power conversion performance, device motions, device loads and device survival.

Guidance on the measurement sensors and data acquisition packages is included but not dictated. Provided that the specified parameters and tolerances are adhered to, selection of the components and instrumentation can be at the device developer's discretion.

An important element of the test protocol is to define the limitations and accuracy of the raw data and, more specifically, the results and conclusion drawn from the trials. A methodology addressing these limitations is presented with each goal, so the plan always produces defendable results of defined uncertainty.

This document serves a wide audience of wave energy stakeholders, including device developers and their technical advisors; government agencies and funding councils; test centres and certification bodies; private investors; and environmental regulators and NGOs.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC TS 62600-2, *Marine energy – Wave, tidal and other water current converters – Part 2: Marine energy systems – Design requirements for marine energy systems*

IEC TS 62600-100, *Marine energy – Wave, tidal and other water current converters – Part 100: Electricity producing wave energy converters – Power performance assessment*

IEC TS 62600-101, *Marine energy – Wave, tidal and other water current converters – Part 101: Wave energy resource assessment and characterization*

3 Terms, definitions, symbols and abbreviated terms

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

3.1.1
dynamic
forces responsible for the object's motion

Note 1 to entry: Dynamic side of absorbed power: "Load measurement" (force, torque, pressure, etc.).

3.1.2
kinematic
motion of object, irrespective of how this motion was caused

Note 1 to entry: Kinematic side of absorbed power: "Velocity measurement" (velocity, angular velocity, flow, etc.).

Note 2 to entry: The terms "dynamic" and "kinematic" as defined above are used extensively throughout this document. These terms are used to ensure that a range of WEC conversion concepts are covered. For example, "dynamic" side of load measurement may refer to forces, torques or pressures, and as such provides a convenient and concise means of relating to a range of technologies.

3.1.3
operational sea states
wave conditions where the wave energy converter is in power production mode

3.1.4
peak distribution
distribution of peak magnitude values

3.1.5
stage 1 <of wave energy converter testing>
small-scale testing in the laboratory

Note 1 to entry: Stage 1 is equivalent to technology readiness level 3.

3.1.6
stage 2 <of wave energy converter testing>
medium-scale testing in the laboratory

Note 1 to entry: Stage 2 is equivalent to technology readiness level 4.

3.1.7
stage 3 <of wave energy converter testing>
first testing at sea

Note 1 to entry: Stage 3 is equivalent to technology readiness level 6.

3.1.8
storm conditions <of a marine energy converter>
sea state with return period as defined in IEC TS 62600-2

3.2 Symbols and abbreviated terms

For the purposes of this document, the following symbols and abbreviated terms apply.

g	Acceleration due to gravity	[m/s^2]
H	Wave height	[m]
H_{m0}	Significant wave height	[m]
J	Wave energy flux	[W/m]
P	Wave power	[W]
T	Wave period	[s]
T_e	Wave energy period	[s]
T_p	Wave peak period	[s]
T_z	Zero up-crossing period	[s]
λ	Length scale factor	[-]
θ	Wave direction	[rad]
ρ	Density	[kg/m^3]

AD	Analogue to digital
CoG	Centre of gravity
DAQ	Data acquisition
DFT	Discrete Fourier transform
DoF	Degree of freedom
FFT	Fast Fourier transform
FMECA	Failures mode, effects, and criticality analysis
IMU	Inertial measurement unit
OWC	Oscillating water column
PCC	Power conversion chain

NOTE The power conversion chain is made up of a drivetrain, generator, storage, and power electronics.

PTO	Power take-off
RAO	Response amplitude operator
SCADA	Supervisory control and data acquisition system
SWL	Still water level
TRL	Technology readiness level
ULS	Ultimate limit state in the context of structural engineering
WEC	Wave energy converter

4 Staged development approach

4.1 General

Clause 4 introduces the staged development of the design for a WEC through physical model testing. Each stage of development is motivated by risk reduction. The primary goals for each stage address elements that shall be completed before proceeding through the user's pre-defined Stage Gate for that stage.

Scaled wave conditions produced in the wave tank should be representative of anticipated full-scale wave conditions at the expected deployment sites, including sea state spectral characteristics.

Figure 1 shows an overview of the process from the early design concept to the deployment of the first limited device number array. Each stage is based on a different physical scale range carefully selected to achieve a set of specific design objectives prior to advancing the device trials to the next stage. This clause outlines the scope and Stage Gates for Stages 1, 2 and 3, guiding the development process from Technology Readiness Level (TRL) 1 to 6 (Figure 1). Stages 4 and 5 (Figure 1) concern commercial scale (or near commercial scale) testing and are not covered in this document.

This document does not dictate a scale for each of the Stages 1 to 3. The model testing scale heavily depends on the type of WEC developed, the fidelity of the available instrumentation, and to some extent on the availability of appropriate test facilities. The scales provided in Figure 1 are included as indicators of previous WEC development efforts.

Every type of WEC will have slightly different requirements so a bespoke programme should be drawn up around these basic testing requirements. The necessary and recommended goals and experimental activities for Stages 1 to 3 are described in detail in Clause 5 to Clause 11. Activities are to be defined in the context of good engineering practice, where factor of safety, reliability or other design philosophy are followed.

Although the ordering of the test schedule is of paramount importance, it is equally essential that a Stage Gate process is applied at the conclusion of each set of trials to evaluate if the WEC has achieved the required experimental objectives before advancing forward. This due diligence should be monitored against the design statement produced by the device developer prior to each stage and the standards being established by the industry based on the other WEC's performances.

A set of Stage Gate criteria for the evaluation of the WEC behaviour and performance at the conclusion of each testing period are defined. These shall be achieved before advancing to the next stage. The criteria are defined as a general framework and allow for a high degree of flexibility to suit the design requirements.

At Stage 1, it should be anticipated that several iterations of a device will be required to optimise the performance, reliability, safety, and economics. More than one iteration may still be required at Stage 2, and a single implementation should normally suffice at Stage 3.