IEC TS 62600-103

Edition 1.0 2018-07

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

IEC TS 62600-103:2018-07(en)

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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 27.140

ISBN 978-2-8322-5831-6

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Technical specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

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

The text of this technical specification is based on the following documents:

Enquiry draft	Report on voting
114/233/DTS	114/259A/RVDTS

Full information on the voting for the approval of this technical specification can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

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 "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

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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 Technical Specification (TS) 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 Clauses 2 and 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 9 to 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), and data acquisition (Clause 8) are also included.

The structured development schedule makes use of the ability to accurately scale WECs 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 WEC'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 WECs since it takes a professional approach to the process. Following these guidelines will not guarantee success, but not following them will be a recipe for lost time and opportunities.

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 WECs. It includes the wave tank test programmes, where wave conditions are controlled so they can be scheduled, and the first large-scale sea trials, where sea states occur naturally and the programmes are adjusted and flexible to accommodate the conditions. A full-scale prototype test schedule is not covered in this document. Bench tests of PTO (power take-off) equipment are also not covered in this document.

This document describes 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. Providing 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 intends to serve 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 62600-1, *Marine energy – Wave, tidal and other water current converters – Part 1: Terminology*

IEC TS 62600-2, *Marine energy – Wave, tidal and other water current converters – Part 2: 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 and acronyms

For the purposes of this document, the terms and definitions given in IEC TS 62600-1 and the following 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 Terms and definitions

3.1.1
cross-sectional load
compressive or tensile stress parallel to the stress plane and shear stress perpendicular to the stress plane

3.1.2
dynamic
forces responsible for the object's motion

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

3.1.3
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.

3.1.4
local load
highly localised impacts like green water, slam event or other impacts that could occur due to motion limitations

3.1.5
regular wave
series of waves containing a single frequency component

3.1.6
operational sea state
wave conditions where the wave energy converter is in power production mode

3.1.7
irregular wave
wave composed of multiple frequency components

3.1.8
peak distribution
distribution of peak magnitude values

3.1.9
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.

3.1.10
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.

3.1.11
stage 3 <of wave energy converter testing>
large-scale testing at sea

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

3.1.12
stationary part of the time series (regular waves)
interval of the time series in which the wave amplitude and frequency result in repeatable values with small standard deviations

3.1.13
stationary part of the time series (irregular waves)
interval of the time series used to analyse the spectral shape of the series

3.1.14
storm conditions
sea state with return period as defined in IEC TS 62600-2

3.1.15
wave train
laboratory generated series of similar period waves

3.1.16
long-crested waves
sea state with little or no directional spreading

3.1.17
short-crested waves
sea state where energy propagation is directionally spread

3.2 Acronyms

CoG	Centre of Gravity
DAQ	Data Acquisition
DoF	Degree of Freedom as defined in IEC TS 62600-1
PCC	Power Conversion Chain. The power conversion chain is made up of a drivetrain, generator, storage, and power electronics.
RAO	Response Amplitude Operator
TRL	Technology Readiness Level
ULS	Ultimate Limit State in the context of structural engineering

4 Staged development approach

4.1 General

This clause 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 full scale (or near full 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 Clauses 5 to 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. At this stage of the technology development, the criteria are defined as a general framework and allow for a high degree of flexibility to suit the particular 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.

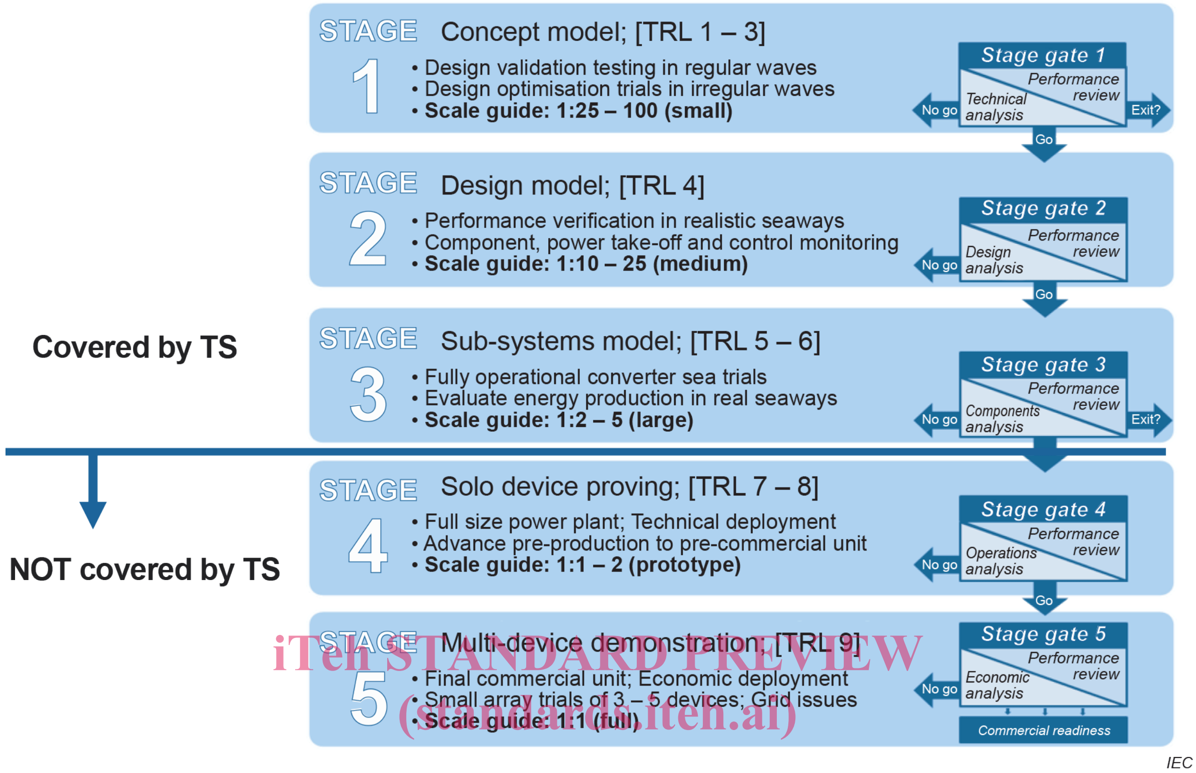

Figure 1 – Staged development approach

4.2 Stage gates

4.2.1 General

At the conclusion of each stage of device model testing, an evaluation procedure should be instigated to assess the overall performance of the design. The appraisal may include a technical and economic review based on three elements of the proposed device design:

- Analysis of the results from the appropriate preceding test programme.
- A comparison with the related device design statement produced at the beginning of the stage.
- An overall design review by a third party, independent, established engineering company.

NOTE See also Annex A for an informative description of the stage gate process.

4.2.2 Criteria

The review shall follow the same set of evaluation criteria at each Stage which are based on the test goals specified for each Stage in Clauses 9, 10 and 11. As the test scale enlarges, the complexity of the model and trials increase to produce more accurate results with less uncertainty in the prototype extrapolation. The Stage Gate evaluation criteria reflect this decreasing uncertainty.

The evaluation criteria shall include

- Energy absorption.
- Device seakeeping (motions).