

# TECHNICAL SPECIFICATION



**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**



## THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2024 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester. If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

IEC Secretariat  
3, rue de Varembe  
CH-1211 Geneva 20  
Switzerland

Tel.: +41 22 919 02 11  
[info@iec.ch](mailto:info@iec.ch)  
[www.iec.ch](http://www.iec.ch)

### About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

### About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

#### IEC publications search - [webstore.iec.ch/advsearchform](http://webstore.iec.ch/advsearchform)

The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee, ...). It also gives information on projects, replaced and withdrawn publications.

#### IEC Just Published - [webstore.iec.ch/justpublished](http://webstore.iec.ch/justpublished)

Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

#### IEC Customer Service Centre - [webstore.iec.ch/csc](http://webstore.iec.ch/csc)

If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: [sales@iec.ch](mailto:sales@iec.ch).

#### IEC Products & Services Portal - [products.iec.ch](http://products.iec.ch)

Discover our powerful search engine and read freely all the publications previews, graphical symbols and the glossary. With a subscription you will always have access to up to date content tailored to your needs.

#### Electropedia - [www.electropedia.org](http://www.electropedia.org)

The world's leading online dictionary on electrotechnology, containing more than 22 500 terminological entries in English and French, with equivalent terms in 25 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

preview generated by EVS

# TECHNICAL SPECIFICATION



**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**

INTERNATIONAL  
ELECTROTECHNICAL  
COMMISSION

ICS 27.140

ISBN 978-2-8322-8963-1

**Warning! Make sure that you obtained this publication from an authorized distributor.**

## CONTENTS

FOREWORD.....	6
INTRODUCTION.....	8
1 Scope.....	9
2 Normative references.....	9
3 Terms, definitions, symbols and abbreviated terms.....	10
3.1 Terms and definitions.....	10
3.2 Symbols and abbreviated terms.....	11
4 Staged development approach.....	12
4.1 General.....	12
4.2 Stage gates.....	13
4.2.1 General.....	13
4.2.2 Criteria.....	13
4.3 Stage 1.....	14
4.3.1 Scope.....	14
4.3.2 Stage Gate 1.....	15
4.4 Stage 2.....	15
4.4.1 Scope.....	15
4.4.2 Stage Gate 2.....	16
4.5 Stage 3.....	16
4.5.1 Scope.....	16
4.5.2 Stage Gate 3.....	17
5 Test planning.....	17
5.1 WEC similitudes.....	17
5.1.1 General.....	17
5.1.2 Power conversion chain (PCC) similitude.....	18
5.2 Design statement.....	19
5.3 Facility selection and outline plan.....	20
5.3.1 General.....	20
5.3.2 Stages 1 and 2.....	20
5.3.3 Stage 3.....	21
5.4 Physical model considerations: Absorbing body and mooring system.....	22
5.4.1 Stage 1.....	22
5.4.2 Stage 2.....	23
5.4.3 Stage 3.....	23
5.5 Physical model considerations: PTO and closed-loop control.....	24
5.5.1 General.....	24
5.5.2 PTO and control design considerations for Stages 1 and 2.....	24
5.5.3 PTO and control design considerations for Stage 3.....	25
5.5.4 PTO bench testing.....	25
6 Reporting and presentation.....	26
6.1 Reporting of test conditions and goals.....	26
6.2 Presentation of results.....	26
6.2.1 General.....	26
6.2.2 Wave parameters.....	26
6.2.3 Response amplitude operators (RAOs) curves.....	27
6.2.4 Scatter diagrams.....	27

- 6.2.5 Alternative iso-variable curves ..... 28
- 6.3 Presentation of performance indicators ..... 28
  - 6.3.1 General ..... 28
  - 6.3.2 Presentation of performance indicators in regular waves ..... 28
  - 6.3.3 Presentation of performance indicators in irregular long-crested waves ..... 29
  - 6.3.4 Presentation of performance indicators in irregular short-crested waves ..... 30
- 7 Testing environment characterisation ..... 30
  - 7.1 General ..... 30
  - 7.2 Wave tank characterisation (Stages 1 and 2) ..... 30
  - 7.3 Trial site characterisation (Stage 3) ..... 32
  - 7.4 Wave characterisation ..... 32
    - 7.4.1 General ..... 32
    - 7.4.2 Laboratory regular waves ..... 32
    - 7.4.3 Laboratory irregular long-crested waves ..... 32
    - 7.4.4 Laboratory irregular short-crested waves ..... 32
    - 7.4.5 Sea trials ..... 32
- 8 Data acquisition and real-time control system ..... 33
  - 8.1 Signal conditioning ..... 33
  - 8.2 Sample rate ..... 34
  - 8.3 Analogue to digital conversion and DAQ system ..... 34
  - 8.4 Frequency response ..... 35
  - 8.5 Data synchronisation ..... 35
  - 8.6 Data recording ..... 35
  - 8.7 Recording of supplementary test data ..... 35
  - 8.8 Calibration factors ..... 36
  - 8.9 Instrument response functions ..... 36
  - 8.10 Health monitoring and verification of signals ..... 36
  - 8.11 Special requirements for Stage 3 sea trials ..... 36
- 9 Power performance ..... 37
  - 9.1 Testing goals ..... 37
  - 9.2 WEC and mooring similitude ..... 37
  - 9.3 Power conversion chain similitude ..... 38
    - 9.3.1 General ..... 38
    - 9.3.2 Stage 1 ..... 39
    - 9.3.3 Stage 2 ..... 39
    - 9.3.4 Stage 3 ..... 39
  - 9.4 Physical measurements ..... 40
  - 9.5 Calibration and setup ..... 40
  - 9.6 Wave parameters ..... 41
    - 9.6.1 Stages 1 and 2 ..... 41
    - 9.6.2 Stage 3 ..... 42
  - 9.7 Performance indicators ..... 42
- 10 Kinematics and dynamics in operational environments ..... 42
  - 10.1 Testing goals ..... 42
  - 10.2 Testing similitude ..... 43
  - 10.3 Physical measurements ..... 44
  - 10.4 Calibration and setup ..... 46
  - 10.5 Wave parameters ..... 47

10.5.1	Stages 1 and 2 .....	47
10.5.2	Stage 3.....	48
10.6	Performance indicators .....	48
11	Kinematics and dynamics in extreme environments .....	49
11.1	Testing goals .....	49
11.2	Testing similitude .....	49
11.3	Physical measurements .....	50
11.4	Calibration and setup .....	51
11.5	Wave parameters.....	51
11.5.1	Stage 1.....	51
11.5.2	Stage 2.....	51
11.5.3	Stage 3.....	52
11.6	Performance indicators .....	53
12	Uncertainty .....	53
12.1	General.....	53
12.2	Main sources of uncertainty .....	54
12.2.1	General .....	54
12.2.2	Variability of measured physical properties including control signals.....	54
12.2.3	Differences between model built and expected full-scale device .....	54
12.2.4	Scale effects and device scale.....	55
12.2.5	Procedural effects .....	55
12.3	Accepted levels of uncertainty .....	56
Annex A (informative)	Stage Gates .....	57
A.1	Overview.....	57
A.2	Design statements .....	57
A.3	Stage Gate criteria.....	57
A.4	Uncertainty factors.....	58
A.5	Concept review .....	59
Annex B (informative)	Example test plan.....	60
Annex C (informative)	Physical modelling guidance .....	61
C.1	Similitude.....	61
C.1.1	General .....	61
C.1.2	Geometric similitude .....	61
C.1.3	Structural similitude .....	61
C.1.4	Hydrodynamic similitude .....	61
C.2	Model instrumentation and data acquisition.....	62
C.2.1	General .....	62
C.2.2	Water surface elevation .....	63
C.2.3	PTO.....	63
C.2.4	Device and mooring loads .....	63
C.3	Recommendations on calibrations.....	63
Annex D (informative)	Scale effects .....	65
Bibliography.....		66
Figure 1 – Staged development approach .....		13
Figure B.1 – Example test plan .....		60

Table 1 – Presentation of performance indicators (regular waves) ..... 29

Table 2 – Presentation of performance indicators (irregular long-crested waves) ..... 29

Table 3 – Presentation of performance indicators (irregular short-crested waves) ..... 30

Table 4 – Environmental measurements ..... 31

Table 5 – Environmental performance indicators ..... 33

Table 6 – Power performance testing similitude ..... 38

Table 7 – Power conversion chain (PCC) representation ..... 38

Table 8 – Power performance physical measurements ..... 40

Table 9 – Power performance calibrations ..... 41

Table 10 – Power performance wave parameters ..... 41

Table 11 – Kinematics and dynamics similitude requirements (operational environments) ..... 44

Table 12 – Kinematic physical measurements (operational environments) ..... 45

Table 13 – Dynamic physical measurements (operational environments) ..... 46

Table 14 – Calibration for kinematic and dynamic testing (operational environments) ..... 47

Table 15 – Wave parameters for kinematics and dynamics testing (operational conditions) ..... 48

Table 16 – Kinematics and dynamics similitude requirements (extreme environments) ..... 50

Table C.1 – Scale laws ..... 62

Table C.2 – Sensor calibrations ..... 64

Table D.1 – Scale example for absorbed power ..... 65

Preview generated by EVS

## INTERNATIONAL ELECTROTECHNICAL COMMISSION

**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**

## FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as “IEC Publication(s)”). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) IEC draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). IEC takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, IEC had not received notice of (a) patent(s), which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at <https://patents.iec.ch>. IEC shall not be held responsible for identifying any or all such patent rights.

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](http://www.iec.ch/members_experts/refdocs). The main document types developed by IEC are described in greater detail at [www.iec.ch/publications](http://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](http://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](http://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 defensible 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.