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Marine environment sensor performance — Specifications, testing and reporting — General requirements

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Contents

Page

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2. www.iso.org/directives

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This document was prepared by Technical Committee ISO/TC 8, *Ships and marine technology*, Subcommittee SC 13, *Marine technology*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Oceans are intertwined with many of humanity's priorities, including trade, food, energy, climate and security. Understanding what's going on below the sea surface is important for making decisions around maritime boundaries, exploiting energy and mineral resources, expanding waterways, and monitoring aquaculture. All depend on the availability of data produced by marine environment sensors that measure physical, ecological and chemical parameters of seawater, such as salinity, temperature, oxygen, carbon dioxide and acidity.

As an example of the growing importance of these data, marine business is increasingly mandated by law to record them to meet environmental regulations. But common definitions for even basic performance specifications of these sensors, such as accuracy or stability, don't exist. This weakens the utility of the laws and diminishes confidence in sensor performance. It also acts to dampen the market forces driving sensor innovation, as it is difficult for end-users to compare and reward true breakthroughs from existing manufacturers, or to trust new entrants. This document aims to address this by establishing a set of performance specifications common to all marine environment sensors, including terms, definitions and test methods.

Marine environment sensor performance — Specifications, testing and reporting — General requirements

1 Scope

This document defines terms, specifies test methods and provides reporting requirements for marine sensor specifications to ensure a consistent reporting by manufacturers.

It is applicable to those devices known as conductivity-temperature-depth (CTDs), sound velocity probes, multi-parameter sondes and dissolved gas sensors, that measure parameters such as conductivity, temperature, pressure, sound speed, dissolved oxygen, turbidity, pH, and chlorophyll in seawater.

It is also generally applicable to all marine environment instruments.

NOTE 1 A 'CTD' directly measures conductivity, temperature, and pressure. Depth is derived from pressure using an equation.

NOTE 2 The term 'sound velocity probe' is widely used to describe instruments that measure sound speed. In this document the term 'sound velocity' is used when describing the type of sensor, and the term 'sound speed' is used when describing the parameter or measurand, but these terms can be used interchangeably.

2 Normative references

The following documents are referred to in the text in such a way that some or all 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.

ISO 5725-2:2019, *Accuracy (trueness and precision) of measurement methods and results — Part 2: Basic method for the determination of repeatability and reproducibility of a standard measurement method*

ISO/IEC 17025:2017, *General requirements for the competence of testing and calibration laboratories*

3 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:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
quantity
parameter
property of a phenomenon, body, or substance, where the property has a magnitude that can be expressed as a number and a reference

Note 1 to entry: A reference can be a measurement unit, a measurement procedure, a reference material, or a combination of such.

EXAMPLE Pressure, *P*

[SOURCE: ISO/IEC Guide 99:2007, 1.1, modified — The admitted term “parameter” has been added. All Notes have been removed except Note 2 to entry, renumbered as Note 1 to entry. The Example has been added.]

3.2
derived quantity
quantity (3.1) that has been calculated from one or more measurements of other quantities

EXAMPLE Absolute salinity, S_A, is calculated from conductivity, temperature and pressure (IOC 56:2010)[8].

3.3
quantity value
value
number and reference together, expressing magnitude of a *quantity* (3.1)

EXAMPLE 1 Conductivity of a volume of seawater: 35 mS/cm or 3, 5 S/m

EXAMPLE 2 Sound speed of a volume of seawater: 1 500 m/s

[SOURCE: ISO/IEC Guide 99:2007, 1.19, modified — All Examples and Notes have been removed. New Examples 1 and 2 have been added.]

3.4
measurand
quantity (3.1) intended to be measured

Note 1 to entry: The specification of a measurand requires knowledge of the kind of quantity, description of the state of the phenomenon, body, or substance carrying the quantity, including any relevant component, and the chemical entities involved.

Note 2 to entry: In the second edition of the VIM and in IEC 60050-300:2001, the measurand is defined as the 'particular quantity subject to measurement'.

Note 3 to entry: The measurement, including the measuring system and the conditions under which the measurement is carried out, might change the phenomenon, body, or substance such that the quantity being measured may differ from the measurand as defined. In this case, adequate correction is necessary.

EXAMPLE 1 The conductivity of a volume of seawater with the ambient Celsius temperature of 23 °C will be different from the conductivity at the specified temperature of 20 °C, which is the measurand. In this case, a correction is necessary.

EXAMPLE 2 The length of a steel rod in equilibrium with the ambient Celsius temperature of 23 °C will be different from the length at the specified temperature of 20 °C, which is the measurand. In this case, a correction is necessary.

[SOURCE: ISO/IEC Guide 99:2007, 2.3, modified — Note 4 has been removed. Example 2 has been changed.]

3.5
measurement
process of experimentally obtaining one or more *quantity values* (3.3) that can reasonably be attributed to a *quantity* (3.1)

[SOURCE: ISO/IEC Guide 99:2007, 2.1, modified — All Notes have been removed.]

3.6
measurement unit
unit
real scalar *quantity* (3.1), defined and adopted by convention, with which any other quantity of the same kind can be compared to express the ratio of the two quantities as a number

Note 1 to entry: Measurement units are designated by conventionally assigned names and symbols.

Note 2 to entry: Measurement units of quantities of the same quantity dimension may be designated by the same name and symbol even when the quantities are not of the same kind. For example, joule per kelvin and J/K are respectively the name and symbol of both a measurement unit of heat capacity and a measurement unit of entropy, which are generally not considered to be quantities of the same kind. However, in some cases special measurement unit names are restricted to be used with quantities of a specific kind only. For example, the measurement unit 'second to the power minus one' (1/s) is called hertz (Hz) when used for frequencies and becquerel (Bq) when used for activities of radionuclides.

EXAMPLE 1 meters per second (m/s)

EXAMPLE 2 millisiemens percentimetre (mS/cm).

EXAMPLE 3 degrees Celsius (°C).

[SOURCE: ISO/IEC Guide 99:2007, 1.9, modified — Notes 3 and 4 have been removed. The Examples have been added.]

3.7
measurement principle
principle of measurement
phenomenon serving as a basis of a *measurement* (3.5)

EXAMPLE 1 Thermoelectric effect applied to the measurement of temperature.

EXAMPLE 2 Photoluminescence effect applied to the measurement of dissolved oxygen.

[SOURCE: ISO/IEC Guide 99:2007, 2.4, modified — All original Examples and Notes have been removed. New Examples 1 and 2 have been added.]

3.8
measurement result
set of *quantity values* (3.3) being attributed to a *measurand* (3.4) together with any other available relevant information

Note 1 to entry: A measurement result generally contains "relevant information" about the set of quantity values, such that some may be more representative of the measurand than others. This may be expressed in the form of a probability density function (PDF).

Note 2 to entry: A measurement result is generally expressed as a single measured quantity value and a measurement uncertainty. If the measurement uncertainty is considered negligible for some purpose, the measurement result may be expressed as a single measured quantity value. In many fields, this is the common way of expressing a measurement result.

[SOURCE: ISO/IEC Guide 99:2007, 2.9, modified — Note 3 has been removed.]

3.9
measurement accuracy
closeness of agreement between a measured quantity value and a true quantity value of a *measurand* (3.4)

Note 1 to entry: The concept "measurement accuracy" is not a quantity and is not given a numerical quantity value. A measurement is said to be more accurate when it offers a smaller measurement error.

Note 2 to entry: The term "measurement accuracy" should not be used for measurement trueness and the term "measurement precision" should not be used for 'measurement accuracy', which, however, is related to both these concepts.

Note 3 to entry: "Measurement accuracy" is sometimes understood as closeness of agreement between measured quantity values that are being attributed to the measurand.

Note 4 to entry: The admitted term "accuracy" has been removed to reduce ambiguation between the concept of 'measurement accuracy' described in ISO/IEC Guide 99, and the method for calculating a marine environment sensor's datasheet accuracy as described in 5.4.

[SOURCE: ISO/IEC Guide 99:2007, 2.13, modified — The admitted term “accuracy” has been removed. Note 4 has been added.]

3.10
measurement trueness
trueness
closeness of agreement between the average of an infinite number of replicate measured quantity values and a reference quantity value

Note 1 to entry: Measurement trueness is not a quantity and thus cannot be expressed numerically, but measures for closeness of agreement are given in ISO 5725.

Note 2 to entry: Measurement trueness is inversely related to systematic measurement error, but is not related to random measurement error.

Note 3 to entry: “Measurement accuracy” should not be used for 'measurement trueness'.

[SOURCE: ISO/IEC Guide 99:2007, 2.14]

3.11
measurement precision
precision
closeness of agreement between *indications* (3.27) or measured quantity values obtained by replicate *measurements* (3.5) on the same or similar objects under specified conditions

Note 1 to entry: Measurement precision is usually expressed numerically by measures of imprecision, such as standard deviation, variance, or coefficient of variation under the specified conditions of measurement.

Note 2 to entry: The 'specified conditions' can be, for example, repeatability conditions of measurement, intermediate precision conditions of measurement, or reproducibility conditions of measurement (see ISO 5725-1:1994).

Note 3 to entry: Measurement precision is used to define measurement repeatability, intermediate measurement precision, and measurement reproducibility.

Note 4 to entry: Sometimes “measurement precision” is erroneously used to mean measurement accuracy.

[SOURCE: ISO/IEC Guide 99:2007, 2.15]

3.12
measurement error
error
measured quantity value minus a reference quantity value

Note 1 to entry: The concept of 'measurement error' can be used both a) when there is a single reference quantity value to refer to, which occurs if a calibration is made by means of a measurement standard with a measured quantity value having a negligible measurement uncertainty or if a conventional quantity value is given, in which case the measurement error is known, and b) if a measurand is supposed to be represented by a unique true quantity value or a set of true quantity values of negligible range, in which case the measurement error is not known.

Note 2 to entry: Measurement error should not be confused with production error or mistake.

[SOURCE: ISO/IEC Guide 99:2007, 2.16]

3.13
systematic measurement error
component of *measurement error* (3.12) that in replicate *measurements* (3.5) remains constant or varies in a predictable manner

Note 1 to entry: A reference quantity value for a systematic measurement error is a true quantity value, or a measured quantity value of a measurement standard of negligible measurement uncertainty, or a conventional quantity value.

Note 2 to entry: Systematic measurement error, and its causes, can be known or unknown. A correction can be applied to compensate for a known systematic measurement error.

Note 3 to entry: Systematic measurement error equals measurement error minus random measurement error.

[SOURCE: ISO/IEC Guide 99:2007, 2.17, modified — The admitted term “systematic error” has been removed.]

3.14
measurement bias
bias
estimate of a *systematic measurement error* (3.13)

[SOURCE: ISO/IEC Guide 99:2007, 2.18]

3.15
repeatability condition of measurement
repeatability condition
condition of measurement, out of a set of conditions that includes the same measurement procedure, same operators, same measuring system, same operating conditions and same location, and replicate *measurements* (3.5) on the same or similar objects over a short period of time

[SOURCE: ISO/IEC Guide 99:2007, 2.20, modified — The Notes have been removed.]

3.16
intermediate precision condition of measurement
intermediate precision condition
condition of measurement, out of a set of conditions that includes the same measurement procedure, same location, and replicate *measurements* (3.5) on the same or similar objects over an extended period of time, but may include other conditions involving changes

Note 1 to entry: The changes can include new calibrations, calibrators, operators, and measuring systems.

[SOURCE: ISO/IEC Guide 99:2007, 2.22, modified — Notes 2 and 3 have been removed.]

3.17
reproducibility condition of measurement
reproducibility condition
condition of measurement, out of a set of conditions that includes different locations, operators, measuring systems, and replicate *measurements* (3.5) on the same or similar objects

[SOURCE: ISO/IEC Guide 99:2007, 2.24, modified — The Notes have been removed.]

3.18
level of the test in a precision experiment
level
average of *measurements* (3.5) from all *sensors* (3.45) for one reference material or measurement standard

[SOURCE: ISO 5725-1:1994, 3.3, modified — The admitted term "level" has been added. The definition has been adapted.]

3.19
cell of a precision experiment
cell
measurement result (3.8) at a single *level* (3.18) obtained by one *sensor* (3.45)

[SOURCE: ISO 5725-1:1994, 3.4, modified — The admitted term "cell" has been added. The definition has been adapted.]

3.20
measurement uncertainty
uncertainty
non-negative parameter characterizing the dispersion of the *quantity values* (3.3) being attributed to a *measurand* (3.4), based on the information used

Note 1 to entry: Measurement uncertainty includes components arising from systematic effects, such as components associated with corrections and the assigned quantity values of measurement standards, as well as the definitional uncertainty. Sometimes estimated systematic effects are not corrected for but, instead, associated measurement uncertainty components are incorporated.

Note 2 to entry: The parameter may be, for example, a standard deviation called standard measurement uncertainty (or a specified multiple of it), or the half-width of an interval, having a stated coverage probability.

Note 3 to entry: Measurement uncertainty comprises, in general, many components. Some of these may be evaluated by Type A evaluation of measurement uncertainty from the statistical distribution of the quantity values from series of measurements and can be characterized by standard deviations. The other components, which may be evaluated by Type B evaluation of measurement uncertainty, can also be characterized by standard deviations, evaluated from probability density functions based on experience or other information.

Note 4 to entry: In general, for a given set of information, it is understood that the measurement uncertainty is associated with a stated quantity value attributed to the measurand. A modification of this value results in a modification of the associated uncertainty.

[SOURCE: ISO/IEC Guide 99:2007, 2.26]

3.21
standard measurement uncertainty
standard uncertainty
measurement uncertainty (3.20) expressed as a standard deviation

[SOURCE: ISO/IEC Guide 99:2007, 2.30]

3.22
combined standard uncertainty
combined uncertainty
standard uncertainty of the result of a measurement when that result is obtained from the values of a number of other *quantities* (3.1), equal to the positive square root of a sum of terms, the terms being the variances or covariances of these other quantities weighted according to how the *measurement result* (3.8) varies with changes in these quantities

[SOURCE: ISO/IEC Guide 98-3:2008, 2.3.4, modified — The admitted term "combined uncertainty" has been added.]

3.23
calibration
operation that establishes a relation between the *quantity values* (3.3) and corresponding *indications* (3.27) of a *sensor* (3.45)

Note 1 to entry: A calibration may be expressed by a statement, calibration function, calibration diagram, calibration curve, or calibration table. In some cases, it may consist of an additive or multiplicative correction of the indication with associated measurement uncertainty.

Note 2 to entry: Calibration should not be confused with adjustment of a measurement system, often mistakenly called "self-calibration", nor with verification of the calibration.

Note 3 to entry: Often, the step of conducting the operation to establish a relation between quantity values and corresponding sensor indications alone is already perceived as being calibration.

[SOURCE: ISO/IEC Guide 99:2007, 2.39, modified — The definition has been truncated for clarity.]

3.24
influence quantity
quantity (3.1) that, in a direct measurement, does not affect the quantity that is actually measured, but affects the relation between the *indication* (3.27) and the *measurement result* (3.8)

EXAMPLE Temperature of the sound velocity sensor, but not the temperature of the surrounding seawater which would enter into the definition of the measurand.

Note 1 to entry: An indirect measurement involves a combination of direct measurements, each of which may be affected by influence quantities.

Note 2 to entry: In the GUM, the concept "influence quantity" is defined as in the second edition of the VIM, covering not only the quantities affecting the measuring system, as in the definition above, but also those quantities that affect the quantities actually measured. Also, in the GUM this concept is not restricted to direct measurements.

[SOURCE: ISO/IEC Guide 99:2007, 2.52, modified — The original Examples have been removed, and a new Example has been added.]

3.25
measuring system
set of one or more measuring *instruments* (3.47) and often other devices, including any reagent and supply, assembled and adapted to give information used to generate measured quantity values within specified intervals for quantities of specified kinds

Note 1 to entry: A measuring system may consist of only one measuring instrument.

[SOURCE: ISO/IEC Guide 99:2007, 3.2]

3.26
adjustment of a measuring system
adjustment

set of operations carried out on a measuring system so that it provides prescribed *indications* (3.27) corresponding to given *values* (3.3) of a *quantity* (3.1) to be measured

Note 1 to entry: Types of adjustment of a measuring system include zero adjustment of a measuring system, offset adjustment, and span adjustment (sometimes called gain adjustment)

Note 2 to entry: Adjustment of a measuring system should not be confused with calibration, which is a prerequisite for adjustment.

Note 3 to entry: After an adjustment of a measuring system, the measuring system must usually be recalibrated.

[SOURCE: ISO/IEC Guide 99:2007, 3.11]

3.27
indication
signal
quantity value (3.3) provided by a *sensor* (3.45) or *instrument* (3.47)

Note 1 to entry: An indication may be presented in visual or acoustic form or may be transferred to another device. An indication is often given by the position of a pointer on the display for analogue outputs, a displayed or printed number for digital outputs, a code pattern for code outputs, or an assigned quantity value for material measures.

Note 2 to entry: An indication and a corresponding value of the quantity being measured are not necessarily values of quantities of the same kind.

[SOURCE: ISO/IEC Guide 99:2007, 4.1, modified — The admitted term "signal" has been added. In the definition, the words "measuring instrument or a measuring system" have been replaced with "sensor or instrument".]

3.28
indication range
range
set of *quantity values* (3.3) bounded by extreme possible *indications* (3.27)

Note 1 to entry: An indication range is usually stated in terms of its smallest and greatest quantity values, for example “0 mS/cm to 100 mS/cm”.

[SOURCE: ISO/IEC Guide 99:2007, 4.3, modified — The original term "indication interval" has been replaced with "indication range" and "range". Note 1 to entry has been adapted ("indication interval" has consistently been replaced with "indication range", and the example "99 V to 201 V" has been replaced with 0 mS/cm to 100 mS/cm"). Note 2 to entry has been removed.]

3.29
calibrated range
set of values of quantities of the same kind bounded by rounded or approximate extreme *levels* (3.18) measured by a given *instrument* (3.47) during calibration

3.30
measuring range
set of values of quantities of the same kind bounded by rounded or approximate extreme *levels* (3.18) measured by a given *instrument* (3.47) during determination of accuracy

[SOURCE: ISO/IEC Guide 99:2007, 4.7, modified — The original term "measuring interval" has been replaced with "measuring range". The definition has been aligned to the definition of *calibrated range* (3.29). The Notes have been removed.]

3.31
maximum range
set of *quantity values* (3.3) of the same kind bounded by rounded or approximate theoretical extreme *levels* (3.18) capable of being measured by a given *instrument* (3.47)

Note 1 to entry: The maximum range is limited only by the sensor model, such as the sensitivity or sensor digitizing electronics.

Note 2 to entry: The maximum range is often larger than the measuring range.

3.32
sensitivity of a measuring system
sensitivity
quotient of the change in an *indication* (3.27) of a measuring system and the corresponding change in a value of a *quantity* (3.1) being measured

Note 1 to entry: Sensitivity of a measuring system can depend on the value of the quantity being measured.

Note 2 to entry: The change considered in a value of a quantity being measured must be large compared to the resolution.

[SOURCE: ISO/IEC Guide 99:2007, 4.12]

3.33
resolution
smallest change in a *quantity* (3.1) being measured that causes a perceptible change in the corresponding *indication* (3.27)

Note 1 to entry: Resolution can depend on, for example, noise (internal or external) or friction. It may also depend on the value of a quantity being measured.

[SOURCE: ISO/IEC Guide 99:2007, 4.14]

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3.34
resolution of a displaying device
digital display
smallest difference between displayed *indications* (3.27) that can be meaningfully distinguished

[SOURCE: ISO/IEC Guide 99:2007, 4.15, modified — The admitted term "digital display" has been added.]

3.35
stability of a measuring instrument
stability
property of a measuring instrument, whereby its metrological properties remain constant in time

Note 1 to entry: Stability consists of the inherent properties of the measuring system related to component ageing or degradation over time and of external factors like biofouling. In both cases it is influenced by the environmental conditions, i.e. the measuring conditions.

Note 2 to entry: Stability is quantified as an "instability", known as drift.

[SOURCE: ISO/IEC Guide 99:2007, 4.19, modified — The original Note has been removed. New Notes 1 and 2 to entry have been added.]

3.36
instrumental drift
drift
continuous or incremental change over time in *indication* (3.27), due to changes in the metrological properties of a measuring instrument

Note 1 to entry: Instrumental drift is related neither to a change in a quantity being measured nor to a change of any recognized influence quantity.

[SOURCE: ISO/IEC Guide 99:2007, 4.21, modified — The admitted term "drift" has been added.]

3.37
calibration curve
expression of the relation between *indication* (3.27) and corresponding measured quantity value

Note 1 to entry: A calibration curve expresses a one to one relation that does not supply a measurement result as it bears no information about the measurement uncertainty.

Note 2 to entry: For a digital sensor, an indication is usually the digital count from an analog to digital convertor.

[SOURCE: ISO/IEC Guide 99:2007, 4.31, modified — Note 2 to entry has been added.]

3.38
instrumental measurement uncertainty
instrument uncertainty
component of *measurement uncertainty* (3.20) arising from a measuring instrument or measuring system in use

Note 1 to entry: Instrumental measurement uncertainty is obtained through calibration of a measuring instrument or measuring system, except for a primary measurement standard for which other means are used.

Note 2 to entry: Instrumental measurement uncertainty is used in a Type B evaluation of measurement uncertainty.

Note 3 to entry: Information relevant to instrumental measurement uncertainty may be given in the instrument specifications.

[SOURCE: ISO/IEC Guide 99:2007, 4.24]