IEC 60500

Edition 2.0 2017-04

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Underwater acoustics – Hydrophones – Properties of hydrophones in the frequency range 1 Hz to 500 kHz

Acoustique sous-marine – Hydrophones – Propriétés des hydrophones dans la bande de fréquences de 1 Hz à 500 kHz

IEC 60500:2017-04(en-fr)

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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

ICS 17.140.50

ISBN 978-2-8322-4049-6

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UNDERWATER ACOUSTICS – HYDROPHONES – PROPERTIES OF HYDROPHONES IN THE FREQUENCY RANGE 1 Hz TO 500 kHz

FOREWORD

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International Standard IEC 60500 has been prepared by IEC technical committee 87: Ultrasonics.

This second edition cancels and replaces the first edition published in 1974. This edition constitutes a technical revision.

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

a) The format and scope of IEC 60500 have been changed to be compatible with IEC 62127-3:2007 in accordance with ISO/IEC Directives, and has a good conformity with IEC 60565:2006, making the suite of available standards for underwater sound a more coordinated and coherent system.
b) The upper limit of the frequency range of hydrophones has been expanded from 100 kHz to 500 kHz.
c) Technical requirements of hydrophone selecting are provided in Annex A, and the depth range of the static pressure range of hydrophones has been expanded from 10 m to 100 m.

The text of this International Standard is based on the following documents:

FDIS	Report on voting
87/644/FDIS	87/649/RVD

Full information on the voting for the approval of this International Standard 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.

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- withdrawn,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.

UNDERWATER ACOUSTICS – HYDROPHONES – PROPERTIES OF HYDROPHONES IN THE FREQUENCY RANGE 1 Hz TO 500 kHz

1 Scope

This document specifies the relevant characteristics and properties of hydrophones in the frequency range 1 Hz to 500 kHz, and specifies how to report these characteristics. It does not cover performance requirements for specific hydrophone types, or for specific hydrophone applications. However, guidance on the choice of a hydrophone with appropriate performance for a specific application is given in an informative annex.

This document is applicable to:

- hydrophones employing piezoelectric sensor elements, designed to respond to sound pressure in water and measure underwater acoustical signals;
- hydrophones with or without an integral pre-amplifier.

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.

ISO 266:1997, *Acoustics – Preferred frequencies*

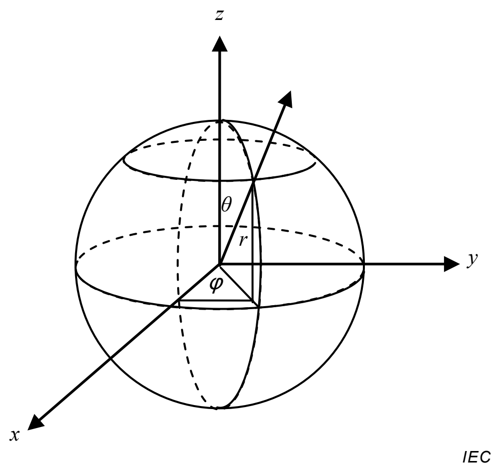
3 Terms and definitions

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

3.1
angular co-ordinate system
system used to designate the directional response pattern of the hydrophone

Note 1 to entry: The terms “horizontal directional response” and “vertical directional response” are often used for representation of directional response in the xy-plane, and xz- (or yz-) planes respectively.

Note 2 to entry: “$+z$” is coincident with an axis of the hydrophone, and “$-z$” is in the direction of the hydrophone cable.



Key

r radial distance

θ polar angle

φ azimuthal angle

Figure 1 – Angular co-ordinate system

3.2
end-of-cable capacitance
C_H
<of a hydrophone> electrical capacitance measured at the end of the integral cable of a hydrophone at a frequency well below any pronounced resonance

Note 1 to entry: End-of-cable capacitance is expressed in farad, F.

Note 2 to entry: The frequency is stated along with the value of end-of-cable capacitance. The end-of cable capacitance is typically measured at a frequency of 1 kHz.

3.3
diffraction factor
ratio of the root-mean-square sound pressure averaged over the part of the hydrophone designed to receive an incident plane wave sound pressure from a given direction to the free-field root-mean-square sound pressure that would exist at the reference centre of the hydrophone if the hydrophone was removed

[SOURCE: IEC 60565:2006 [1] [1], 3.4, modified – Replace “averaged pressure” with “root-mean-square sound pressure averaged”, “receive sound” with “receive an incident plane wave sound pressure from a given direction”, “free-field sound pressure” with “free-field root-mean-square sound pressure”, and add “if the hydrophone was removed”.]

3.4
directional response
<of a hydrophone> description, generally presented graphically, of the response of a hydrophone, as a function of the direction of propagation of the incident plane sound wave, in a specified plane through the reference centre, at a specified frequency

Note 1 to entry: The directional response pattern is usually presented in the form of a two dimensional polar graph. The scale of the polar may be in terms of sensitivity level or as relative values normalized to the sensitivity in a specified direction (often the direction of the principal axis). The relative values are sometimes presented in decibels as a relative directional response level. See Figure 1 for description of angular co-ordinate system.

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1 Numbers in square brackets refer to the Bibliography.

[SOURCE: IEC 62127-3:2007 [2], 3.1, modified – Add the specific context "<of a hydrophone>" and Note 1 to entry.]

3.5
dynamic range
twenty times the logarithm to the base 10 of the ratio of the overload sound pressure in a specified frequency band that produces an undistorted hydrophone output to the equivalent bandwidth noise pressure at the hydrophone

Note 1 to entry: Dynamic range is expressed in decibel, dB.

[SOURCE: IEC 60565:2006 [1], 3.6, modified – Replace “ratio” with “twenty times the logarithm to the base 10 of the ratio”, “maximum free-field sound pressure” with “overload sound pressure in a specified frequency band”, and “equivalent noise pressure” with “equivalent bandwidth noise pressure”.]

3.6
electrical impedance
$\underline{Z}$
<of a hydrophone> complex valued quantity, the modulus of which is the ratio of the root-mean-square voltage applied across the electrical terminals of a hydrophone to the resulting root-mean-square current, and the argument of which is the phase difference between voltage and current, at a specified frequency

Note 1 to entry: Electrical impedance of a hydrophone is expressed in ohm, Ω.

Note 2 to entry: Because the electrical impedance depends on the hydrostatic pressure, water temperature and the length of the cable attached to the hydrophone, these parameters, as well as the frequency and the electrical terminals where the electrical impedance is measured, should be specified.

3.7
electrical terminals
<of a hydrophone> terminals across which the open-circuit voltage of a hydrophone is measured

3.8
end-of-cable
specification that relates to the end of the integral cable of a hydrophone with or without an integral pre-amplifier

Note 1 to entry: If the hydrophone is not provided with an integral cable, the specification relates to the output connector firmly connected with the hydrophone, not any additional extension cable.

[SOURCE: IEC 62127-3:2007 [2], 3.4, modified – Replace “integral output cable if the hydrophone or hydrophone assembly is provided with such a cable; if the hydrophone or hydrophone assembly is not provided with an integral output cable, the specification relates to the output connector firmly connected with the hydrophone or hydrophone assembly, not to an extra cable” with “integral cable of a hydrophone with or without an integral pre-amplifier”. Add Note 1 to entry.]

3.9
end-of-cable leakage resistance
R_{L}
ratio of the root-mean-square voltage across the end-of-cable electrical terminals of a hydrophone to the direct root-mean-square current flowing through these terminals

Note 1 to entry: End-of-cable leakage resistance is expressed in ohm, Ω.

Note 2 to entry: The value of the voltage used during the determination of the end-of-cable leakage resistance should be stated.

[SOURCE: IEC 60866:1987 [3], 3.13, modified – Replace "voltage across the electrical terminals at the end of the hydrophone cable to the direct current" with "root-mean-square voltage across the end-of-cable electrical terminals of a hydrophone to the direct root-mean-square current".]

3.10
equivalent bandwidth noise pressure
p_W
ratio of the root-mean-square noise voltage in the relevant frequency band present at the electrical terminals of the hydrophone, in the absence of sound pressure or pressure fluctuations at the hydrophone input, to its sensitivity in a specified frequency band

Note 1 to entry: Equivalent bandwidth noise pressure is expressed in pascal, Pa.

3.11
equivalent noise pressure spectral density
p_s
equivalent bandwidth noise pressure when its bandwidth is 1 Hz

Note 1 to entry: Equivalent noise pressure spectral density is expressed in pascal per square root of hertz, Pa · Hz$^{-1/2}$.

3.12
equivalent noise pressure spectral density level
twenty times the logarithm to the base 10 of the ratio of the equivalent noise pressure spectral density of a hydrophone, p_s, to a reference pressure spectral density, p_{s0}

Note 1 to entry: Equivalent noise pressure spectral density level of a hydrophone is expressed in decibel, dB.

Note 2 to entry: The value of reference pressure spectral density, p_{s0}, is 1 µPa · Hz$^{-1/2}$.

3.13
free field
sound field in a homogeneous and isotropic medium in which the effects of the boundaries are negligible

[SOURCE: IEC 60565:2006 [1], 3.13]

3.14
free-field open-circuit complex sensitivity
$\underline{M}_f$
complex valued quantity, the modulus of which is the free-field open-circuit sensitivity and the argument of which is the sensitivity phase angle, for specified frequency and specified direction of sound incidence at the position of the reference centre of the hydrophone if the hydrophone was removed from the sound field

3.15
free-field open-circuit sensitivity
M_f
modulus of the free-field open-circuit complex sensitivity, which is equal to the ratio of the open-circuit root-mean-square voltage at the end-of-cable of a hydrophone to the root-mean-square sound pressure for specified frequency and specified direction of plane wave sound incident on the position of the reference centre of the hydrophone in the undisturbed free field if the hydrophone was removed

Note 1 to entry: Free-field open-circuit sensitivity is expressed in volt per pascal, V/Pa.

Note 2 to entry: The term 'response' is sometimes used instead of 'sensitivity'.

3.16
free-field open-circuit sensitivity level
twenty times the logarithm to the base 10 of the ratio of the free-field open-circuit sensitivity, M_{f}, to a reference sensitivity, M_{ref}

Note 1 to entry: Free-field open-circuit sensitivity level is expressed in decibel, dB.

Note 2 to entry: The value of reference sensitivity, M_{ref}, is 1 V/µPa.

3.17
hydrophone
electroacoustic transducer that produces electrical signals in response to water borne pressure signals

Note 1 to entry: A hydrophone is designed to respond principally to underwater sound pressure.

Note 2 to entry: In general, a hydrophone may also produce a signal in response to non-acoustic pressure fluctuations (for example, those existing in a turbulent boundary layer during conditions of high water flow).

Note 3 to entry: Hydrophone types include reference hydrophones and measuring hydrophones. Measuring hydrophones are used in general measurements of sound fields, and reference hydrophones are principally used for calibration purposes (for example in comparison calibrations with measuring hydrophones).

Note 4 to entry: Hydrophones are principally used for listening devices, but in reciprocity calibration, a hydrophone is used as reciprocal transducer, not only acting as a hydrophone, but also as a projector (sound source).

Note 5 to entry: A hydrophone which is integrated with a digital acquisition system is sometimes termed a “digital hydrophone”, but the combination is best considered as a measuring system, not a hydrophone alone.

Note 6 to entry: If a hydrophone is connected to a charge amplifier, the sensitivity of the hydrophone is sometimes described in terms of charge sensitivity, which is related to the voltage sensitivity of the hydrophone by its electrical capacitance.

[SOURCE: IEC 60565:2006 [1], 3.16, modified – Replace “transducer” with “electroacoustic transducer”, and “water borne acoustic signals” with “water borne pressure signals”. Replace the note with Notes 1 to 6 to entry.]

3.18
open-circuit voltage
U_{H}
voltage appearing at the electrical terminals of a hydrophone when no current passes through the terminals

Note 1 to entry: Open-circuit voltage at hydrophone is expressed in volt, V.

[SOURCE: IEC 60565:2006 [1], 3.19, modified – Delete "at hydrophone" from the term.]

3.19
overload sound pressure
p_{o}
ratio of the maximum root-mean-square sound pressure applied at the hydrophone to cause a distorted voltage output with specified criteria (linearity) to a reference sound pressure at a specified frequency

Note 1 to entry: Overload sound pressure is expressed in pascal, Pa.

Note 2 to entry: The distortion tolerance criteria should be specified.

3.20
overload sound pressure level
twenty times the logarithm to the base 10 of the ratio of the overload sound pressure, p_{o}, to a reference sound pressure, p_{o0}

Note 1 to entry: Overload sound pressure level is expressed in decibel, dB.

Note 2 to entry: The value of reference sound pressure, p_{o0}, is 1 µPa.

3.21
phase angle

argument of the free-field open-circuit complex sensitivity, which is equal to the phase difference between open-circuit voltage at the end-of-cable of a hydrophone and sound pressure for specified frequency and specified direction of plane-wave sound incident on the position of the reference centre of the hydrophone in the undisturbed free field if the hydrophone was removed

3.22
pre-amplifier

active electronic device, often integrated into a particular hydrophone design, reducing the hydrophone output impedance and amplifying the hydrophone output signal

Note 1 to entry: A pre-amplifier requires an electrical power supply voltage.

Note 2 to entry: The pre-amplifier may have a forward voltage transmission factor of less than one, i.e. it need not necessarily be a voltage amplifier in the strict sense.

Note 3 to entry: If a differential amplifier is used as the pre-amplifier, its gain is usually termed a differential output gain, and this will be a factor of 2 higher than for an equivalent single-ended pre-amplifier (6 dB increase in level). The sensitivity of the hydrophone and pre-amplifier combination is then termed the differential output sensitivity.

[SOURCE: IEC 62127-3:2007 [2], 3.12, modified – Delete "hydrophone" from the term. Replace “connected to, or to be connected to, a particular hydrophone” with “, often integrated into a particular hydrophone design,”, and add “and amplifying the hydrophone output signal”. Replace the notes with Notes 1 to 3 to entry.]

3.23
pressure sensitivity

M_p

<of a hydrophone> ratio of the root-mean-square output voltage to the root-mean-square sound pressure averaged over the active element of the hydrophone designed to receive sound, at a specified frequency

Note 1 to entry: Pressure sensitivity of a hydrophone is expressed in volt per pascal, V/Pa.

Note 2 to entry: The term ‘response’ is sometimes used instead of ‘sensitivity’.

[SOURCE: IEC 60565:2006 [1], 3.22, modified – Replace “output voltage” with “root-mean-square output voltage”, “actual sound pressure existing over the region of hydrophone” with “root-mean-square sound pressure averaged over the active element of the hydrophone”, and add “at a specified frequency”. Replace the notes with Notes 1 and 2 to entry.]

3.24
pressure sensitivity level

twenty times the logarithm to the base 10 of the ratio of the pressure sensitivity, M_p, to a reference sensitivity of M_{ref}

Note 1 to entry: Pressure sensitivity level is expressed in decibel, dB.

Note 2 to entry: The value of reference sensitivity M_{ref} is 1V/µPa.

[SOURCE: IEC 60565:2006 [1], 3.21].

3.25
principal axis

reference direction serving as an origin for the angular co-ordinate system used in describing the directional characteristics of the hydrophone

Note 1 to entry: Generally, the axis of structural symmetry or the direction of maximum response is chosen for the principal axis. See Figure 1 for description of angular co-ordinate system.

Note 2 to entry: The direction of maximum response may vary with the frequency of the sound.

[SOURCE: IEC 60565:2006 [1], 3.23, modified – Replace “transducer” with “hydrophone”.]

3.26
reference centre
point on, within or near a hydrophone about which its geometrical electroacoustic characteristics are defined

Note 1 to entry: The reference centre often corresponds to the geometrical centre of a hydrophone, unless otherwise stated.

[SOURCE: IEC 60565:2006 [1], 3.25, modified – Replace “point on or near a transducer” with “point on, within or near a hydrophone”, and “acoustic receiving sensitivity and transmitting responses” with “geometrical electroacoustic characteristics”. Replace note with Note 1 to entry.]

3.27
sound pressure
p
difference between total pressure and pressure that would exist in the absence of sound

Note 1 to entry: Sound pressure is expressed in pascal, Pa.

Note 2 to entry: This definition follows the convention adopted with ISO for the definition of sound pressure such that it is an instantaneous quantity. Note that in IEC 60050-801-21 [4] (IEV), this term is called “instantaneous sound pressure”. In this document, where the root-mean-square sound pressure is intended, this is explicitly referred to as “root-mean-square sound pressure”.

Note 3 to entry: See also ISO 80000-8:2007 [5], 8.9.2.

[SOURCE: ISO 18405:—[2] [6], 2.1.2.1]

3.28
uncertainty
<of measurement> parameter, associated with the result of a measurement, that characterizes the dispersion of the values that could reasonably be attributed to the measurand

[SOURCE: ISO/IEC Guide 98-3:2008 [7], 2.2.3]

4 Symbols

C_{H} end-of-cable capacitance

f frequency

$\underline{M}_{\mathrm{f}}$ free-field open-circuit complex sensitivity

M_{f} free-field open-circuit sensitivity

M_{p} pressure sensitivity

p sound pressure

p_{o} overload sound pressure

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[2] Under preparation. Stage at the time of publication: ISO/DIS 18405:2016.

p_w equivalent bandwidth noise pressure

p_s equivalent noise pressure spectral density

R_L end-of-cable leakage resistance

U_H open-circuit voltage

$\underline{Z}$ electrical impedance

5 Hydrophone characteristics

5.1 General

The hydrophones used in underwater acoustics shall be generally of the piezoelectric type, with or without an integral pre-amplifier. In order to fully characterize the performance of a hydrophone, the information given in 5.2 to 5.10 is required. The recommended information to be supplied by the manufacturer is simply summarized in Clause 6.

5.2 Basic requirements

The following shall be briefly stated:

- the basic physical principle of the transduction process;
- the type of element material, its form and the element size;
- the electrical capacitance of the sensor element;
- the type, configuration and overall size of the hydrophone;
- for a hydrophone with pre-amplifier, a simple circuit diagram, supply power requirements and the connections of the pre-amplifier shall be given;
- the position of the reference centre of the hydrophone element within the overall hydrophone body (important for phase measurement considerations);
- the calibrated directional response of a hydrophone;
- the frequency of the fundamental resonance of the hydrophone sensor element;
- the cable length of the hydrophone;
- the mass with or without cable;
- the serial number and the manufacturer’s model number;
- the hydrophone sensitivity, including any frequency dependence over the operating frequency range.

If phase information is required, the sensitivity phase angle (which equals the argument of the complex sensitivity) shall be stated in addition to the sensitivity magnitude (which equals the modulus of the complex sensitivity), as well as the frequency dependence of the phase angle.

5.3 Sensitivity

The sensitivity of a hydrophone shall be expressed in S.I. units of volts per pascal (V/Pa) or any allowed sub-multiple within the S.I. convention. It shall be stated whether the sensitivity value given is understood as the free-field open-circuit sensitivity or the pressure sensitivity.

The uncertainty of the stated sensitivity shall be given.

For a hydrophone with pre-amplifier, the gain of the pre-amplifier with the frequency dependence shall be stated.

The sensitivity level of the hydrophone shall be expressed in decibels, and the reference value of sensitivity shall be given.

The frequency or frequency interval over which the sensitivity is applicable shall be stated. The methods by which the sensitivity and its uncertainty have been obtained shall be described.

A recommended calibration period shall be provided in the instructions for use. This recommendation shall be followed, unless otherwise stated by specific device application standards.

A calibration period of one year will be appropriate in most cases. However, if a hydrophone is used in an application in which the hydrophone is susceptible to damage, the calibration period should be less than one year.

NOTE The value of reference sensitivity in the calculation of the sensitivity level is 1 V/µPa.

5.4 Frequency response

5.4.1 Stated operating frequency band

The operating frequency band claimed for the hydrophone shall be stated by giving the lower frequency limit and the upper frequency limit. The sensitivity of the hydrophone shall be uniform over the stated frequency band, with a tolerance which shall also be stated.

5.4.2 Frequency dependence

The sensitivity or sensitivity level of the hydrophone as a function of frequency shall be stated either graphically or as a list of values and over a frequency range containing at least the frequency band claimed under 5.4.1. If it is given as a list of values or as discrete points in a graph, the frequency interval between adjacent points shall be narrow enough that all important details of the frequency dependence are shown, and the sensitivity level does not vary by more than ±1 dB between adjacent points.

If the sensitivity response is given as a list of absolute sensitivity values, the sensitivity statement in accordance with 5.3 may be omitted.

NOTE 1 The frequency response may depend on the electrical loading conditions.

NOTE 2 If, in a practical application, the hydrophone is used with subsequent electronic components such as an amplifier, digitizer, etc., the frequency response of the whole system will also be influenced by the frequency response of these additional components [8, 9].

5.5 Directional response

Usually, the directional response of the hydrophone is stated at the four highest preferred frequencies of the specified frequency range claimed under 5.4.1 in accordance with ISO 266. The directional response close to the fundamental resonance shall also be stated if this resonance is inside the claimed operating frequency band. The method used to determine the directional response shall be stated.

Each of the resulting directional responses obtained from the measurements shall be stated.

5.6 Dynamic range

5.6.1 Linearity and overload sound pressure level

The linear range of the hydrophone shall be stated, i.e. the sound pressure range in which the hydrophone behaves in a linear way according to the condition below.