SLOVENSKI STANDARD
oSIST prEN IEC 62127-3:2022

01-maj-2022

Ultrazvok - Hidrofoni - 3. del: Lastnosti hidrofonov za ultrazvočna polja

Ultrasonics - Hydrophones - Part 3: Properties of hydrophones for ultrasonic fields

Ultraschall - Hydrophone - Teil 3: Eigenschaften von Hydrophonen zur Verwendung in Ultraschallfeldern

Ultrasons - Hydrophoes - Partie 3: Propriétés des hydrophones pour les champs ultrasoniques jusqu'à 40 MHz

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IEC

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COMMITTEE DRAFT FOR VOTE (CDV)

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IEC TC 87 : ULTRASONICS	
SECRETARIAT: United Kingdom	SECRETARY: Mr Petar Luzajic
OF INTEREST TO THE FOLLOWING COMMITTEES:	PROPOSED HORIZONTAL STANDARD: ☐ Other TC/SCs are requested to indicate their interest, if any, in this CDV to the secretary.
FUNCTIONS CONCERNED: ☐ EMC ☐ ENVIRONMENT	☐ QUALITY ASSURANCE ☐ SAFETY
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TITLE:

Ultrasonics - Hydrophones - Part 3: Properties of hydrophones for ultrasonic fields

PROPOSED STABILITY DATE: 2025

NOTE FROM TC/SC OFFICERS:

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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ULTRASONICS – HYDROPHONES –

Part 3: Properties of hydrophones for ultrasonic fields

FOREWORD

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This second edition cancels and replaces the first edition published in 2007-08 and its amendment 1 (2013-05). This edition constitutes a technical revision.

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

a) The upper frequency limit of 40 MHz has been removed;

b) Hydrophone sensitivity definitions have been changed to recognize sensitivities as complex-valued quantities;

c) Procedures to determine the effective hydrophone size have been changed according to the rationale outlined in Annex B;

d) Requirements on the frequencies for which the effective hydrophone size shall be provided have been changed to achieve practicality for increased frequency bands;

e) The new Annexes B and C have been added;

f) Annex A has been updated to reflect the changes of the normative parts.

International Standard IEC 62127-3 has been prepared by IEC technical committee 87: Ultrasonics.

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

A list of all parts of IEC 62127 series, published under the general title *Ultrasonics – Hydrophones,* can be found on the IEC website.

NOTE Words in **bold** in the text are defined in Clause 3.

The committee has decided that the contents of the base publication and its amendment will remain unchanged until the maintenance result date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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

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INTRODUCTION

The spatial and temporal distribution of acoustic pressure in an ultrasonic field in a liquid medium is commonly determined using miniature ultrasonic **hydrophones**. The properties of these **hydrophones** have been dealt with in a number of IEC standards in various aspects. The purpose of this part of IEC 62127 is to bring together all these specifications and to establish a common standard on the properties of ultrasonic **hydrophones**. The main **hydrophone** application in this context is the measurement of ultrasonic fields emitted by medical diagnostic equipment in water. Other medical applications are field measurements for therapy equipment such as that used in lithotripsy, high-intensity focused ultrasound (HIFU) and physiotherapy. **Hydrophones** are also used extensively in non-medical applications for both product development and quality control including:

– mapping of the ultrasound field within ultrasonic cleaning baths;

– characterization of acoustic fields used in transmission measurement systems (e.g. ultrasonic spectrometers, ultrasonic attenuation meters and velocimeters);

– characterization of acoustic fields used in reflection measurement systems (e.g. Doppler flowmeters).

While the term "**hydrophone**" can be used in a wider sense, it is understood here as referring to miniature piezoelectric **hydrophones**. It is this instrument type that is used today in various areas of ultrasonics and, in particular, to quantitatively characterize the field structure of medical diagnostic instruments. With regard to other pressure sensor types, such as those based on fibre optics, some of the requirements of this standard are applicable to these as well but others are not. If in the future these other "**hydrophone**" types gain more importance in field measurement practice, their properties will have to be dealt with in a revised version of this document or in a separate one.

Underwater **hydrophones** as covered by IEC 60500, IEC 60565-1, and IEC 60565-2 are not included in this document, although there is an overlap in the frequency ranges. Underwater **hydrophones** are used in natural waters, even in the ocean, and this leads to different technical concepts and requirements. In addition, the main direction of acoustic incidence in underwater applications is at various angles and often at right angles to the **hydrophone axis**, whereas this standard it is assumed that the main direction of acoustic incidence is in the direction of the **hydrophone axis**.

Historically, ultrasonic **hydrophones** were used almost exclusively as amplitude sensors. However, the complex-valued nature of a **hydrophone's** system response function is well understood and IEC 62127-1 Ed 2 makes use of this within the deconvolution procedures it contains. In this document, requirements are specified for the amplitude aspect of the **hydrophone** sensitivity and recommendations are provided for the phase aspect which can be derived either via calibration, or via calculation methods that are discussed in IEC 62127-1 Ed 2.

ULTRASONICS – HYDROPHONES –

Part 3: Properties of hydrophones for ultrasonic fields

1 Scope

This part of IEC 62127 specifies relevant **hydrophone** characteristics.

This standard is applicable to:

– **hydrophones** employing piezoelectric sensor elements, designed to measure the pulsed and continuous wave ultrasonic fields generated by ultrasonic equipment;

– **hydrophones** used for measurements made in water;

– **hydrophones** with or without an associated pre-amplifier.

2 Normative references

The following referenced documents are indispensable for the application 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 62127-1, *Ultrasonics – Hydrophones – Part 1: Measurement and characterization of medical ultrasonic fields up to 40 MHz*

IEC 62127-2, *Ultrasonics – Hydrophones – Part 2: Calibration for ultrasonic fields up to 40 MHz*

3 Terms, definitions and symbols

For the purposes of this document, the terms and definitions given in IEC 62127-1, IEC 62127-2 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
acoustic pulse waveform
temporal waveform of the **instantaneous acoustic pressure** at a specified position in an acoustic field and displayed over a period sufficiently long to include all significant acoustic information in a single pulse or tone-burst, or one or more cycles in a continuous wave

Note 1 to entry: Temporal waveform is a representation (e.g. oscilloscope presentation or formula) of the **instantaneous acoustic pressure**.

[SOURCE: IEC 62127-1:2007 and Amendment 1:2013, definition 3.1]

3.2
directional response
description of the response of a **hydrophone**, as a function of direction of propagation of the incident plane sound wave, in a specified plane through the **reference centre** and at a specified frequency

NOTE 1 Definition adopted from IEC 60565:2006.

NOTE 2 Whilst **directional response** is a complex-valued function, it is generally the magnitude of **directional response** that is of most interest and this commonly presented graphically.

3.3
effective hydrophone size
a_h

size of a theoretical receiver **hydrophone** that has a predicted **directional response** function with an angular width equal to the observed angular width

NOTE 1 The size is usually the function of frequency. For representative experimental data, see [1].

NOTE 2 The effective hydrophone size is expressed in metres (m).

NOTE 3 For hydrophones with a circular geometry, the **effective hydrophone size** is a radius.

NOTE 4 For hydrophones with a rectangular geometry, the **effective hydrophone size** is the half the greatest value of the length or width.

3.4
electric load impedance
$\underline{Z}_L$
complex electric input impedance (consisting of a real and an imaginary part) to which the **hydrophone** or **hydrophone assembly** output is connected or is to be connected

NOTE The electric load impedance is expressed in ohms (Ω).

3.5
end-of-cable
specification that relates to the end of the integral output cable if the **hydrophone** or **hydrophone assembly** is provided with such a cable and 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

3.6
end-of-cable loaded sensitivity
$\underline{M}_L(f)$
<of a **hydrophone** or **hydrophone assembly**> quotient of the Fourier transformed **hydrophone** voltage-time signal $\mathcal{F}(u_L(t))$ at the end of any integral cable or output connector of a **hydrophone** or **hydrophone-assembly**, when connected to a specified **electric load impedance**, to the Fourier transformed **acoustic pulse waveform** $\mathcal{F}(p(t))$ in the undisturbed free field of a plane wave in the position of the **reference centre** of the **hydrophone** if the **hydrophone** were removed

$$\underline{M}_L(f) = \frac{\mathcal{F}(u_L(t))}{\mathcal{F}(p(t))} \tag{1}$$

Note 1 to entry: The **end-of-cable loaded sensitivity** is a complex-valued parameter. Its modulus is expressed in units of volt per pascal (V/Pa), its phase angle is expressed in degrees, and represents the phase difference between the electrical voltage and the sound pressure.

3.7
end-of-cable open-circuit sensitivity
$\underline{M}_c(f)$
<of a **hydrophone**> quotient of the Fourier transformed **hydrophone** open-circuit voltage-time signal $\mathcal{F}(u_c(t))$ at the end of any integral cable or output connector of a **hydrophone** to the Fourier transformed **acoustic pulse waveform** $\mathcal{F}(p(t))$ in the undisturbed free field of a

plane wave in the position of the **reference centre** of the **hydrophone** if the **hydrophone** were removed

$$\underline{M}_{\mathrm{C}}(f) = \frac{\mathcal{F}(u_{\mathrm{C}}(t))}{\mathcal{F}(p(t))} \tag{2}$$

Note 1 to entry: The **end-of-cable open-circuit sensitivity** is a complex-valued parameter. Its modulus is expressed in units of volt per pascal (V/Pa), its phase angle is expressed in degrees, and represents the phase difference between the electrical voltage and the sound pressure.

3.8

end-of-cable loaded sensitivity level

$L_{M_{\mathrm{L}}}(f)$

<of a **hydrophone** or **hydrophone assembly**> twenty times the logarithm to the base 10 of the quotient of the modulus of the **end-of-cable loaded sensitivity** $|\underline{M}_{\mathrm{L}}(f)|$ to a reference sensitivity M_{ref}

$$L_{M_{\mathrm{L}}}(f) = 20\log_{10}\frac{|\underline{M}_{\mathrm{L}}(f)|}{M_{\mathrm{ref}}}\,\mathrm{dB} \tag{3}$$

Note 1 to entry: Commonly used values of the reference sensitivity M_{ref} are 1V/µPa or 1V/Pa.

Note 2 to entry: The **end-of-cable loaded sensitivity level** is expressed in decibels (dB).

3.9

free field

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

Note 1 to entry: Definition adopted from IEC 60565:2006, 3.13.

3.10

hydrophone geometrical size

geometrical size of a hydrophone active element

a_{g}

size defined by the lateral extents of the active element of a **hydrophone**

Note 1 to entry: The **hydrophone geometrical** size is expressed in metres (m).

Note 2 to entry: For hydrophones with a circular geometry, the **hydrophone geometrical size** is a radius.

Note 3 to entry: For hydrophones with a rectangular geometry, the **hydrophone geometrical size** is a half the greatest value of the length or width.

3.11

hydrophone

transducer that produces electric signals in response to waterborne acoustic signals

[SOURCE: IEV 801-32-26]

3.12

hydrophone assembly

combination of **hydrophone** and **hydrophone pre-amplifier**

3.13

hydrophone axis

nominal symmetry axis of the **hydrophone** active element

Note 1 to entry: Unless stated otherwise (explicitly and quantitatively) by the manufacturer, it is understood for the purposes of this standard that this is given by the apparent geometrical symmetry axis of the **hydrophone**.

3.14
hydrophone pre-amplifier
active electronic device connected to, or to be connected to, a particular **hydrophone** and reducing its output impedance

Note 1 to entry: A **hydrophone pre-amplifier** requires a supply voltage (or supply voltages).

Note 2 to entry: The **hydrophone 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.

3.15
reference centre
point on or near a **hydrophone** about which its acoustic receiving sensitivity is defined

Note 1 to entry: Unless stated otherwise (explicitly and quantitatively) by the manufacturer, it is understood for the purposes of this standard that this is given by the geometrical centre of the front surface of the **hydrophone** active element.

Note 2 to entry: Definition adopted from IEC 60565:2006, 3.25.

3.16
uncertainty
parameter, associated with the result of a measurement, that characterizes the dispersion of the values that could reasonably be attributed to the measurand

Note 1 to entry: See the ISO *Guide to the Expression of Uncertainty in Measurement* [2], 2.2.3

Note 2 to entry: Definition adopted from IEC 62127-1.

4 List of symbols

a_g	**hydrophone geometrical size**
a_h	**effective hydrophone size**
c	speed of sound in a medium
D_H	model function used during the determination of **effective hydrophone size** from a measured **directional response** of a **hydrophone**
f	frequency
k	wavenumber = $2\pi / \lambda$
$L_{M_L}(f)$	**end-of-cable loaded sensitivity level**
$\underline{M}$	general symbol for the complex **hydrophone** sensitivity, $M = \lvert \underline{M} \rvert$ being its modulus and arg($\underline{M}$) being its argument (= phase angle)
$\underline{M}_c$	end-of-cable open-circuit sensitivity
$\underline{M}_L$	end-of-cable loaded sensitivity
$\underline{Z}_h$	complex electric output impedance of a **hydrophone** or **hydrophone assembly**
$\underline{Z}_L$	electric load impedance
θ	angle of incidence of an ultrasonic wave with respect to the **hydrophone axis**