

Specification for

**Measurement and
characterisation of
ultrasonic fields using
hydrophones in the
frequency
range 0.5 MHz
to 15 MHz**

The European Standard EN 61102:1993 has the status of a
British Standard

UDC 621.396:534.86

Cooperating organizations

The European Committee for Electrotechnical Standardization (CENELEC), under whose supervision this European Standard was prepared, comprises the national committees of the following countries:

Austria	Italy
Belgium	Luxembourg
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Finland	Norway
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Germany	Spain
Greece	Sweden
Iceland	Switzerland
Ireland	United Kingdom

This British Standard, having been prepared under the direction of the Electronic Equipment Standards Policy Committee, was published under the authority of the Standards Board and comes into effect on 15 April 1994

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The following BSI references relate to the work on this standard:
Committee reference EEL/35
Draft for comment 88/29416 DC

ISBN 0 580 23009 0

Amendments issued since publication

Amd. No.	Date	Comments
8224	July 1994	Indicated by a sideline in the margin

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National foreword

This British Standard has been prepared under the direction of the Electronic Equipment Standards Policy Committee and is the English language version of EN 61102:1993 *Measurement and characterisation of ultrasonic fields using hydrophones in the frequency range 0,5 MHz to 15 MHz*, including Amendment A1 published by the European Committee for Electrotechnical Standardization (CENELEC). It is identical with IEC 1102:1991 published by the International Electrotechnical Commission (IEC).

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Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, the EN title page, pages 2 to 46, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

UDC 621.396:534.86

Descriptors: Ultrasound, ultrasonic field, hydrophone, measurement

English version

Measurement and characterisation of ultrasonic fields using hydrophones in the frequency range 0,5 MHz to 15 MHz

(include amendment A1:1994)
(IEC 1102:1991)

Mesurage et caractérisation des champs
ultrasonores à l'aide d'hydrophones dans la
gamme de fréquences de 0,5 MHz à 15 MHz
(Inclut l'amendement A1:1994)
(CEI 1102:1991)

Messung und Beschreibung von
Ultraschallfeldern mit Hydrophonen im
Frequenzbereich von 0,5 MHz bis 15 MHz
(enthält Änderungen A1:1994)
(IEC 1102:1991)

This European Standard was approved by CENELEC on 1993-09-22. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the Central Secretariat has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.

CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

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Foreword

The CENELEC questionnaire procedure, performed for finding out whether or not the International Standard IEC 1102:1991 could be accepted without textual changes, has shown that no common modifications were necessary for acceptance as a European Standard.

The reference document was submitted to the CENELEC members for formal vote and was approved by CENELEC as EN 61102 on 22 September 1993.

The following dates were fixed:

- latest date of publication of an identical national standard (dop) 1994-10-01
- latest date of withdrawal of conflicting national standards (dow) 1994-10-01

Annexes designated “normative” are part of the body of the standard. Annexes designated “informative” are given only for information. In this standard, Annex A, Annex B, Annex C and Annex D are informative and Annex ZA is normative.

Foreword to Amendment A1

The text of document 87(CO)30, as prepared by IEC Technical Committee 87: Ultrasonics, was submitted to the IEC-CENELEC parallel vote in April 1993.

The reference document was approved by CENELEC as amendment A1 to EN 61102 on 8 December 1993.

The following dates were fixed:

- latest date of publication of an identical national standard (dop) 1994-12-01
- latest date of withdrawal of conflicting national standards (dow) 1994-12-01

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Introduction

The main purpose of this International Standard is to define various acoustic parameters which can be used to specify and characterise ultrasonic fields propagating in liquids, and in particular water, using hydrophones. Measurement procedures are outlined which may be used to determine these parameters. There is much in common between this International Standard and the AIUM/NEMA Safety Standard [1]. However, whilst every effort has been made to try to maintain consistency with the AIUM/NEMA Standard, there are fundamental differences in approach.

The philosophy behind this International Standard is the specification of the acoustic field in terms of acoustic pressure parameters, acoustic pressure being the primary measurement quantity when hydrophones are used to characterise the field. Of course, if other measurement devices come into use in the future, a new International Standard with additional definitions and procedures will be necessary. Examples of such devices would be thermistors or thermocouples.

Intensity parameters similar to those given in [1] are specified in this International Standard, but these are regarded as derived quantities which are meaningful only under certain assumptions related to the ultrasonic field being measured.

Alternative simplified procedures that may be used when less accuracy is required will be given in an IEC Guidance Document (in preparation).

This amendment defines alternative procedures for the measurement of acoustic pressure and derived intensity parameters for the sound fields generated by single ultrasonic transducers which have cylindrical or spherical active elements and defines additional acoustical terms.

1 Scope

This International Standard specifies the methods of use of calibrated piezoelectric hydrophones for the measurement in liquids of acoustic fields generated by ultrasonic medical equipment operating in the frequency range 0,5 MHz to 15 MHz.

The objectives of this International Standard are

- To define a group of acoustic parameters which can be measured on a physically sound basis.
- To define a second group of parameters which can be derived under certain assumptions from these measurements, and called derived intensity parameters.
- To define a measurement procedure which may be used for the determination of acoustic pressure parameters.
- To define the conditions under which the measurements of acoustic parameters can be made in the frequency range 0,5 MHz to 15 MHz using calibrated piezoelectric hydrophones.

NOTE Throughout this International Standard SI units are used. In the specification of certain parameters, such as beam-areas and intensities, it may be convenient to use other units. For example, beam-area may be specified in cm^2 and intensities in W/cm^2 or mW/cm^2 .

2 Normative references

The following standards contains provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 50(801), *International Electrotechnical Vocabulary (IEV), Chapter 801: Acoustics and electro-acoustics* (1984).

IEC 469-1:1987, *Pulse techniques and apparatus — Part 1: Pulse terms and definitions*.

IEC 854:1986, *Methods of measuring the performance of ultrasonic pulse-echo diagnostic equipment*.

IEC 866:1987, *Characteristics and calibration of hydrophones for operation in the frequency range 0,5 MHz to 15 MHz*.

3 Definitions

For the purposes of this International Standard, the following definitions apply.

3.1

acoustic pulse crest factor

ratio of the **spatial-peak temporal-peak acoustic pressure** to the r.m.s. **acoustic pressure** calculated over the **pulse-peak cycle**. Both pressures are measured at the position in the acoustic field corresponding to the **spatial-peak temporal-peak acoustic pressure**

3.2

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. See 2.3.1 of IEC 469-1

3.3

acoustic repetition period

pulse repetition period for non-automatic scanning systems and the **scan repetition period** for automatic scanning systems. Equal to the time interval between consecutive cycles for continuous-wave systems

unit: second, s

3.4

acoustic-working frequency (awf)

frequency of an acoustic signal based on the observation of the output of a **hydrophone** placed in an acoustic field at the position corresponding to the **spatial-peak temporal-peak acoustic pressure**. The signal is analysed either using the zero-crossing frequency technique or using a spectrum analysis method. The following acoustic-working frequencies are defined:

3.4.1

zero-crossing acoustic-working frequency

this is determined according to the procedure described in IEC 854

for the spectral analysis method the acoustic pressure versus frequency is displayed and there are three different methods of deriving the acoustic-working frequency which, referring to Figure 1, are:

3.4.2

arithmetic-mean acoustic-working frequency

the arithmetic mean of the frequencies f_1 and f_2 at which the amplitude of the acoustic pressure spectrum is 3 dB below the peak amplitude

3.4.3

geometric-mean acoustic-working frequency

the geometrical mean of the frequencies f_1 and f_2

3.4.4

modal acoustic-working frequency

the frequency corresponding to the maximum amplitude in the acoustic pressure spectrum

NOTE Arithmetic-mean acoustic-working frequency is equivalent to center frequency in [1].

Symbol: f_{awf}

Unit: hertz, Hz.

3.5

beam-alignment axis

used for alignment purposes only, beam-alignment axis is a straight line joining two points of **spatial-peak temporal-peak acoustic pressure** on two hemispherical surfaces whose centres are at the approximate geometrical centre of an **ultrasonic transducer** or **ultrasonic transducer element group**. One hemisphere has a radius of curvature of approximately $A_g/\pi\lambda$, where A_g is the **geometrical area of the ultra-sonic transducer** or **ultrasonic transducer element group** and λ is the wavelength of the ultrasound corresponding to the nominal frequency. The second hemisphere has a radius of curvature either $2A_g/\pi\lambda$, or $A_g/3\pi\lambda$, whichever is the more appropriate. For the purposes of alignment, this line may be projected to the face of the **ultrasonic transducer** or **ultrasonic transducer element group**

for most practical applications, two plane surfaces perpendicular to the direction of propagation of the ultrasound are used. In cases where a unique peak is not located on a hemispherical surface, another hemispherical surface is chosen with a different radius of curvature yielding a unique peak (See Figure 2)

3.6

beam-area

area on a specified surface consisting of all points at which the **pulse-pressure-squared integral** is greater than a specified fraction of the maximum value of the **pulse-pressure-squared integral** in that surface. The specified surface is cylindrical for **ultrasonic transducers** with cylindrical active elements and spherical for **ultrasonic transducers** with spherical active elements, and at a specified radius. The specified levels are 0,25 and 0,01 for the – 6 dB and – 20 dB **beam-areas**, respectively

3.7

beam-average pulse acoustic pressure

pulse acoustic pressure from one **ultra-sonic transducer** or **ultrasonic transducer element group** averaged over the – 6 dB **beam-area** in a specified surface or in a surface containing the **spatial-peak temporal-peak acoustic pressure** for that particular **ultrasonic transducer** or **ultrasonic transducer element group**

NOTE – 6 dB **beam-area** is commonly used. However, other **beam-areas** may be used (see 3.6).

Symbol: p_{bap}

Unit: pascal, Pa.

3.8

beam-average pulse-average intensity

pulse-average intensity from one **ultra-sonic transducer** or **ultrasonic transducer element group** averaged over the – 6 dB **beam-area** in a specified surface or in a surface containing the **spatial-peak temporal-peak acoustic pressure** for that particular **ultrasonic transducer** or **ultrasonic transducer element group**

NOTE – 6 dB **beam-area** is commonly used. However, other **beam-areas** may be used (see 3.6).

Symbol: I_{bapa}

Unit: watt per metre squared, W/m².

3.9

beam-average r.m.s. acoustic pressure

R.M.S. acoustic pressure from one **ultrasonic transducer** or **ultrasonic transducer element group** averaged over the – 6 dB **beam-area** in a specified surface or in a surface containing the **spatial-peak temporal-peak acoustic pressure** for that particular **ultrasonic transducer** or **ultrasonic transducer element group**

NOTE – 6 dB **beam-area** is commonly used. However, other **beam-areas** may be used (see 3.6).

Symbol: p_{bar}

Unit: pascal, Pa.

3.10**beam-average temporal-average intensity**

temporal-average intensity from one **ultrasonic transducer** or **ultrasonic transducer element group** averaged over the **- 6 dB beam-area** in a specified surface or in a surface containing the **spatial-peak temporal-peak acoustic pressure** for that particular **ultrasonic transducer** or **ultrasonic transducer element group**

NOTE - **6 dB beam-area** is commonly used. However, other **beam-areas** may be used (see 3.6).

Symbol: I_{bata}

Unit: watt per metre squared, W/m².

3.11**central scan line**

for automatic scanning systems, the **ultrasonic scan line** closest to the **symmetry axis of the scan plane**

3.12**effective area of an ultrasonic transducer**

area of a perfect piston-like **ultra-sonic transducer** which has a predicted axial acoustic pressure distribution approximately equivalent to the observed axial acoustic pressure distribution over a limited axial distance, see IEC 866

Symbol: A_1

Unit: metre squared, m².

3.13**effective radius of a hydrophone active element**

radius of a stiff disc receiver **hydrophone** which has a predicted directional response function with an angular width equal to the observed angular width. The angular width is determined at a specified level below the peak of the directional response function

for the specified levels of 3 dB and 6 dB, the radii are denoted by a_3 and a_6 respectively

Symbols: a , a_3 , a_6

Unit: metre, m.

3.14**end-of-cable loaded sensitivity of a hydrophone**

ratio of the voltage at the end of any integral cable or connector of a **hydrophone**, when connected to a specified electrical input impedance, to the **instantaneous acoustic pressure** in the undisturbed free field of a plane wave in the position of the acoustic centre of the **hydrophone** if the **hydrophone** were removed

Symbol: M_L

Unit: volt per pascal, V/Pa.

3.15**end-of-cable open-circuit sensitivity of a hydrophone**

ratio of the open-circuit voltage at the end of any integral cable or connector of a **hydrophone** to the **instantaneous acoustic pressure** in the undisturbed free field of a plane wave in the position of the acoustic centre of the **hydrophone** if the **hydrophone** were removed, see IEC 866

NOTE This definition differs from that given in 3.8 of IEC 866 as the latter refers to a hydrophone excluding any integral cable.

Symbol: M_c

Unit: volt per pascal, V/Pa.

3.16**far field**

acoustic (sound) field at distances from an **ultrasonic transducer** where the values of the **instantaneous acoustic pressure** and particle velocity are substantially in phase, see also 801-03-30 of IEC 50(801)

for the purposes of this International Standard, although strictly for planar ultrasonic transducers, the far field is at a distance greater than $A_1/\pi\lambda$, where A_1 is the **effective area of the ultrasonic transducer or ultrasonic transducer element group** and λ , is the wave-length of the ultrasound corresponding to the **acoustic-working frequency**

3.17

geometrical area of an ultrasonic transducer

area defined by the **ultrasonic transducer** dimensions or **ultrasonic transducer element group** dimensions

Symbol: A_g

Unit: metre squared, m^2 .

3.18

geometrical radius of a hydrophone active element

radius defined by the dimensions of the **active element of a hydrophone**

Symbol: a_g

Unit: metre, m.

3.19

hydrophone

transducer that produces electrical signals in response to waterborne acoustic signals, see also 801-12-26 of IEC 50(801) and also IEC 866

3.20 instantaneous acoustic pressure; instantaneous sound pressure

pressure amplitude minus the ambient pressure at a particular instant in time and at a particular point in an acoustic field, see also 801-01-19 of IEC 50(801)

Symbol: p

Unit: pascal, Pa.

3.21

instantaneous intensity

acoustic energy transmitted per unit time in the direction of acoustic wave propagation per unit area normal to this direction at a particular instant in time and at a particular point in an acoustic field

it is not possible to measure the true instantaneous intensity. However, for historical reasons, it is preferable in this International Standard to derive certain intensity parameters from hydrophone measurements. Therefore, for the measurement purposes referred to in this International Standard, and if it is reasonable to assume **far field** conditions, the **instantaneous intensity**, I is expressed as

$$I = \frac{p^2}{\rho c}$$

where:

p is the **instantaneous acoustic pressure**;

ρ is the density of the medium;

c is the velocity of sound in the medium.

Symbol: I

Unit: watt per metre squared, W/m^2 .

3.22

mean-peak-cycle acoustic pressure

arithmetic mean of the maximum positive and modulus of the maximum negative **instantaneous acoustic pressure** during a **pulse-peak cycle**

Symbol: p_m

Unit: pascal, Pa.

3.23**near field**

for the purposes of this International Standard, the region of the acoustic (sound) near field an **ultrasonic transducer** where the relative phase of the **instantaneous acoustic pressure** and the particle velocity is continually changing with position in the acoustic (sound) field

for planar transducers, this is at a distance less than $A_1/\pi\lambda$, where A_1 is the **effective area of the ultrasonic transducer** or **ultrasonic transducer element group** and λ is the wavelength of the ultrasound corresponding to the **acoustic-working frequency**

3.24**nominal frequency**

ultrasonic frequency of operation of an **ultrasonic transducer** or **ultrasonic transducer element group** quoted by the designer or manufacturer, see IEC 854

3.25**nonlinear propagation parameter**

index which permits the prediction of nonlinear distortion of ultrasound for a specific **ultrasonic transducer**, and is given by σ_m from:

$$\sigma_m = \frac{\beta\omega l_1}{\rho c^3} p_m \frac{1}{(F_g - 1)^{1/2}} \ln((F_g - 1)^{1/2} + F_g^{1/2})$$

where:

- β is the nonlinearity parameter ($\beta = 1 + B/2A = 3,5$ for pure water at 20 °C [2]);
- ω is the angular frequency ($\omega = 2\pi f_{awf}$ where f_{awf} is the **acoustic-working frequency**);
- l_1 is the distance from the face of the **ultrasonic transducer** to the plane containing the point of **spatial-peak temporal-peak acoustic pressure**;
- F_g is 0,69 times the ratio of the **geometrical area of the ultrasonic transducer** to the **- 6 dB beam-area**;
- p_m is the **mean-peak-cycle acoustic pressure** at the point in the acoustic field corresponding to the **spatial-peak temporal-peak acoustic pressure**.

Symbol: σ_m

NOTE The equation given above is applicable to ultrasonic fields in which $F_g > 2,1$. The specification of an index to cover $F_g \leq 2,1$ is under consideration.

3.26**peak-negative acoustic pressure; peak-rarefactional acoustic pressure**

maximum of the modulus of the negative **instantaneous acoustic pressure** in an acoustic field or in a specified surface during an **acoustic repetition period**. **Peak-negative acoustic pressure** is expressed as a positive number

Symbol: p_- (or p_r)

Unit: pascal, Pa.

3.27**peak-positive acoustic pressure; peak-compressional acoustic pressure**

maximum positive **instantaneous acoustic pressure** in an acoustic field or in a specified surface during an **acoustic repetition period**

Symbol: p_+ (or p_c)

Unit: pascal, Pa.

3.28**pulse acoustic pressure**

square root of the ratio of the **pulse-pressure-squared integral** to the **pulse duration** at a particular point in an acoustic field

Symbol: p_p

Unit: pascal, Pa.

3.29**pulse-average intensity**

ratio of the **pulse-intensity integral** to the **pulse duration** at a particular point in an acoustic field

Unit: watt per metre squared, W/m².

3.30**pulse duration**

1,25 times the interval between the time when the time integral of the square of the **instantaneous acoustic pressure** reaches 10 per cent and 90 per cent of its final value. The final value of the time integral of the square of the **instantaneous acoustic pressure** is the **pulse-pressure-squared integral**

Symbol: t_d

Unit: second, s.

3.31**pulse-intensity integral**

time integral of the **instantaneous intensity** at a particular point in an acoustic field integrated over the **acoustic pulse waveform**

NOTE For many measurement purposes referred to in this International Standard, **pulse-intensity integral** is proportional to **pulse-pressure-squared integral**.

Symbol: I_{pi}

Unit: joule per metre squared, J/m².

3.32**pulse-peak cycle**

single cycle of an **acoustic pulse waveform** between two points of zero **instantaneous acoustic pressure**. This single cycle is composed of the half cycle containing the **temporal-peak acoustic pressure** and whichever of the two adjacent half cycles contains the larger peak **instantaneous acoustic pressure**

3.33**pulse-pressure-squared integral**

time integral of the square of the **instantaneous acoustic pressure** at a particular point in an acoustic field integrated over the **acoustic pulse waveform**

Symbol: p_i

Unit: pascal squared second, pa²s.

3.34**pulse repetition period**

time interval between two successive pulses or tone-bursts. This applies to single element non-automatic scanning systems and automatic scanning systems. See also **5.3.2.1** of IEC 469-1

Unit: second, s.

3.35**pulse repetition rate (p.r.r.)**

inverse of the **pulse repetition period**. See also 5.3.2.2 of IEC 469-1

Symbol: prf

Unit: hertz, Hz.

3.36**R.M.S. acoustic pressure**

root mean square (r.m.s.) of the **instantaneous acoustic pressure** at a particular point in an acoustic field. The mean should be taken over an integral number of **acoustic repetition periods** unless otherwise specified

Symbol: p_{rms}

Unit: pascal, Pa.

3.37**scan-area**

for automatic scanning systems, the area on the surface considered consisting of all points within the **beam-area** of any beam passing through the surface during the **scan repetition period**

Symbol: A_s

Unit: metre squared, m^2 .

3.38**scan plane**

for automatic scanning systems, a plane containing all the **ultrasonic scan lines**

3.39**scan repetition period**

time interval between identical points on two successive frames, sectors or scans. This applies to automatic scanning systems only

Unit: second, s.

3.40**scan repetition rate (s.r.r.)**

inverse of the **scan repetition period**

Unit: hertz, Hz.

3.41**spatial-average pulse acoustic pressure**

for non-automatic scanning systems, the **beam-average pulse acoustic pressure**

NOTE **Spatial-average pulse acoustic pressure** does not apply to automatic scanning systems, **beam-average pulse acoustic pressure** applies only.

Symbol: p_{sap}

Unit: pascal, Pa.

3.42**spatial-average pulse-average intensity**

for non-automatic scanning systems, the **beam-average pulse-average intensity**

NOTE **Spatial-average pulse-average intensity** does not apply to automatic scanning systems, **beam-average pulse-average intensity** applies only.

Symbol: I_{sapa}

Unit: watt per metre squared, W/m^2 .