

This is a preview - click here to buy the full publication



IEC 62127-2

Edition 1.0 2007-08

INTERNATIONAL STANDARD

**Ultrasonics – Hydrophones –
Part 2: Calibration for ultrasonic fields up to 40 MHz**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

PRICE CODE **XC**

ICS 17.140.50

ISBN 2-8318-9277-5

CONTENTS

FOREWORD.....	5
INTRODUCTION.....	7
1 Scope.....	8
2 Normative references.....	8
3 Terms, definitions and symbols.....	9
4 List of symbols.....	13
5 Overview of calibration procedures.....	15
5.1 Principles.....	15
5.2 Summary of calibration procedures.....	16
5.3 Reporting of results.....	17
5.4 Recommended calibration periods.....	18
6 Generic requirements of a hydrophone calibration system.....	19
6.1 Mechanical positioning.....	19
6.1.1 General.....	19
6.1.2 Accuracy of the axial hydrophone position.....	19
6.1.3 Accuracy of the lateral hydrophone position.....	19
6.2 Temperature measurements and temperature stability.....	19
6.3 Hydrophone size.....	20
6.4 Measurement vessel and water properties.....	20
6.5 Measurement of output voltage.....	20
7 Electrical considerations.....	21
7.1 Signal type.....	21
7.2 Earthing.....	21
7.3 Measurement of hydrophone output voltage.....	21
7.3.1 General.....	21
7.3.2 Electrical loading by measuring instrument.....	21
7.3.3 Electrical loading by extension cables.....	22
7.3.4 Noise.....	22
7.3.5 Cross-talk (radio-frequency <i>rf</i> pick-up) and acoustic interference.....	22
7.3.6 Integral hydrophone pre-amplifiers.....	23
8 Preparation of hydrophones.....	23
8.1 General.....	23
8.2 Wetting.....	23
8.3 Hydrophone support.....	23
8.4 Influence of cable.....	23
9 Free field reciprocity calibration.....	23
9.1 General.....	23
9.2 Object.....	23
9.3 General principles.....	24
9.3.1 General.....	24
9.3.2 Three-transducer reciprocity calibration method.....	24
9.3.3 Self-reciprocity calibration method.....	24
9.3.4 Two-transducer reciprocity calibration method.....	24
9.4 Two-transducer reciprocity calibration method.....	24
9.4.1 Apparatus.....	24

9.4.2 Procedure	25
10 Free field calibration by planar scanning	25
10.1 General	25
10.2 Object	25
10.3 General principle	25
10.4 Procedural requirements	27
10.4.1 Hydrophone scanning	27
10.5 Procedure	27
10.5.1 Power measurement	27
10.5.2 Transducer mounting	27
10.5.3 Measurement conditions	27
10.5.4 Measurements	28
10.6 Corrections and sources of uncertainty	28
11 Free field calibration by optical interferometry	28
11.1 General	28
11.2 Principle	28
12 Calibration by comparison using a standard hydrophone	28
12.1 General	28
12.2 Object	28
12.3 Principle	29
12.4 Procedural requirements	29
12.4.1 Source transducer	29
12.4.2 Source transducer drive signal	29
12.4.3 Measurement system	29
12.5 Procedure	30
12.5.1 Measurements (Type I): determination of the directional response of a hydrophone	30
12.5.2 Measurements (Type II): calibration by comparison using a standard hydrophone	30
12.6 Maximum hydrophone size	31
Annex A (informative) Assessment of uncertainty in free field calibration of hydrophones	32
Annex B (informative) Behaviour of PVDF polymer sensors in high intensity ultrasonic fields	34
Annex C (informative) Electrical loading corrections	37
Annex D (informative) Absolute calibration of hydrophones using the planar scanning technique	38
Annex E (informative) Properties of water	46
Annex F (informative) The absolute calibration of hydrophones by optical interferometry up to 40 MHz	48
Annex G (informative) Waveform concepts	58
Annex H (informative) Time delay spectrometry – requirements and a brief review of the technique	68
Annex I (informative) Determination of the phase response of hydrophones	71
Annex J (informative) Maximum size considerations for the active element of a hydrophone	77

Bibliography	79
Figure F.1 – Experimental set-up of the interferometric foil technique	51
Figure F.2 – End-of-cable open-circuit sensitivity, M_C , of a coplanar membrane hydrophone	53
Figure F.3 – Hydrophone waveform generated by a 9 μm coplanar membrane hydrophone positioned at the focus of a 5 MHz transducer (focal length 51 mm)	54
Figure F.4 – Interferometer (displacement) waveform generated with the pellicle positioned at the focus of the 5 MHz transducer (focal position 51 mm)	55
Figure F.5 – Frequency spectrum of the displacement waveform (lower curve) and the differentiated displacement waveform (upper curve)	55
Figure F.6 – Sensitivity of a 0,2 mm active element diameter of a 9 μm bilaminar membrane hydrophone determined at 5 MHz intervals over the frequency range 5 MHz to 60 MHz	56
Figure G.1 – Coordinates of a field point, P, in the near field of a plane- circular source transducer of radius, a_t	65
Figure I.1 – Phase of end-of-cable open-circuit sensitivity for two membrane hydrophones	73
Figure I.2 – Phase of end-of-cable open-circuit sensitivity for a \varnothing 0,2 mm needle hydrophone	75
Table 1 – List of typical uncertainty values obtained by the calibration methods specified in this standard and for the frequency range listed here	17
Table E.1 – Speed of sound c and specific acoustic impedance, ρc , as a function of temperature, for propagation in water	46
Table G.1 – Temporal waveform and hydrophone position concepts described in this Annex	58
Table I.1. – Example of uncertainties (where a coverage factor, $k = 2$, is used) for a HTDS phase calibration of a needle hydrophone with a diameter of 0,2 mm, expressed at a confidence level of 95 %	73

INTERNATIONAL ELECTROTECHNICAL COMMISSION

ULTRASONICS – HYDROPHONES –

Part 2: Calibration for ultrasonic fields up to 40 MHz

FOREWORD

- 1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC provides no marking procedure to indicate its approval and cannot be rendered responsible for any equipment declared to be in conformity with an IEC Publication.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

International Standard IEC 62127-2 has been prepared by IEC technical committee 87: Ultrasonics.

IEC 62127-1, IEC 62127-2 and IEC 62127-3 are being published simultaneously. Together these cancel and replace IEC 60866:1987, IEC 61101:1991, IEC 61102:1991, IEC 61220:1993 and IEC 62092:2001.

The text of this standard is based on the following documents:

Enquiry draft	Report on voting
87/353/CDV	87/372/RVC

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

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 this publication 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.

A bilingual version of this publication may be issued at a later date.

The contents of the corrigendum of August 2008 have been included in this copy.

INTRODUCTION

The spatial and temporal distribution of acoustic pressure in an ultrasonic field in a liquid medium is commonly determined using miniature ultrasonic **hydrophones**. These devices are not absolute measurement instruments and require calibration. The purpose of this part of IEC 62127 is to specify those calibration methods to be used in determining the response of a **hydrophone** in the ultrasonic range, i.e. above 20 kHz up to a frequency of 40 MHz. The main **hydrophone** application in this context lies in the measurement of ultrasonic fields emitted by medical diagnostic equipment in water. **Hydrophone** behaviour over this wide frequency band is required in order to reliably characterize the acoustic parameters of the applied acoustic field. In particular, the frequency range above 15 MHz is important to fully characterize this equipment, primarily due to the increased appearance of high-frequency components in the ultrasonic signals, caused by non-linear propagation. In addition, the number of medical ultrasonic systems that use frequencies above 15 MHz, particularly intra-operative probes, is growing. It has turned out in recent years that the **hydrophone** response below 0,5 MHz is also required to reliably determine the peak-negative (rarefactional) acoustic pressure.

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 medical ultrasonics and, in particular, to characterize quantitatively 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 characteristics and calibration will have to be dealt with in a revised version of this standard or in a separate one.

NOTE This standard covers the ultrasonic frequency range, from 20 kHz to an upper frequency of 40 MHz. Standards dealing with **hydrophone** properties (IEC 62127-3) and **hydrophone** use (IEC 62127-1) are being developed in parallel as part of a programme of maintenance activities aimed at restructuring and merging, where possible, all existing ultrasonic **hydrophone** standards. This will eventually lead to unified standards covering the whole field of practical **hydrophone** application.

ULTRASONICS — HYDROPHONES —

Part 2: Calibration for ultrasonic fields up to 40 MHz

1 Scope

This part of IEC 62127 specifies:

- absolute **hydrophone** calibration methods;
- relative (comparative) **hydrophone** calibration methods.

Recommendations and references to accepted literature are made for the various relative and absolute calibration methods in the frequency range covered by this standard.

This standard is applicable to

- **hydrophones** used for measurements made in water and in the ultrasonic frequency range up to 40 MHz;

NOTE 1 Although some physiotherapy medical applications of medical ultrasound are developing which operate in the frequency range 40 kHz to 100 kHz, the primary frequency range of diagnostic imaging remains above 2 MHz. It has recently been established that, even in the latter case, the **hydrophone** response at substantially lower frequencies can influence measurements made of key acoustic parameters [1].

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

NOTE 2 Some hydrophones can have non-circular active elements, arising from slight deviations from a circular structure caused, for example by electrode structure, or conversely, the active elements can actually be squares. The clauses within this standard remain valid, although, in these cases, special attention should be paid to the directional response and to the effective radii of the active element through various axes of rotation.

- **hydrophones** with or without a hydrophone 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 60050-801:1994, *International Electrotechnical Vocabulary – Chapter 801: Acoustics and electro-acoustics*

IEC 60565, *Underwater acoustics – Hydrophones – Calibration in the frequency range 0,01 Hz to 1 MHz*

IEC 61161:2006, *Ultrasonics – Power measurement – Radiation force balances and performance requirements*

IEC 61828:2006, *Ultrasonics – Focusing transducers – Definitions and measurement methods for the transmitted fields*

IEC 62127-1, *Ultrasonics – Hydrophones – Part 1: Measurement and characterization of medical ultrasonic fields up to 40 MHz*

IEC 62127-3, *Ultrasonics – Hydrophones – Part 3: Properties of hydrophones for ultrasonic fields up to 40 MHz*