

AS/NZS 4190:1994  
IEC 1220:1993

## Australian/New Zealand Standard

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**Ultrasonics—Fields—Guidance for  
the measurement and  
characterization of ultrasonic fields  
generated by medical ultrasonic  
equipment using hydrophones in  
the frequency range 0.5 MHz to  
15 MHz**

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This Joint Australian/New Zealand Standard was prepared by Joint Technical Committee HT/17, Ultrasonic Medical Equipment. It was approved on behalf of the Council of Standards Australia on 7 March 1994 and on behalf of the Council of Standards New Zealand on 28 February 1994. It was published on 16 May 1994.

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The following interests are represented on Committee HT/17:

CSIRO—Department of Radiophysics  
Public Works Department, N.S.W.

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First published as Joint Standard AS/NZS 4190:1994.

PUBLISHED JOINTLY BY:

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Homebush NSW 2140 Australia

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## PREFACE

This Standard was prepared by the Joint Standards Australia/Standards New Zealand Committee HT/17 on Ultrasonic Medical Equipment, and issued as a Joint Standard under the terms of the Active Cooperation Agreement between Standards Australia and Standards New Zealand.

This Standard is identical with and has been reproduced from IEC 1220:1993, *Ultrasonics—Fields—Guidance for the measurement and characterization of ultrasonic fields generated by medical ultrasonic equipment using hydrophones in the frequency range of 0,5 MHz to 15 MHz*.

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| <i>Reference to International Standard<br/>or other publication</i>                                                                                                                                                  | <i>Australian/New Zealand Standard</i> |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------|
| IEC                                                                                                                                                                                                                  | AS/NZS                                 |
| 1101 The absolute calibration of hydrophones using the planar scanning technique in the frequency range 0,5 MHz to 15 MHz                                                                                            | —                                      |
| 1102 Measurement and characterization of ultrasonic fields using hydrophones in frequency range of 0,5 MHz to 15 MHz.                                                                                                | —                                      |
| Amendment 1: Definitions of additional terms and specific requirements for the characterization of fields from ultrasonic transducers having cylindrical or spherical active elements ( <i>under consideration</i> ) | —                                      |
| 1161 Ultrasonic power measurement in liquids in the frequency range of 0,5 MHz to 25 MHz                                                                                                                             | —                                      |

The term ‘informative’ has been used in this Standard to define the application of the annex to which it applies. An ‘informative’ annex is only for information and guidance.

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## STANDARDS AUSTRALIA/STANDARDS NEW ZEALAND

**Australian/New Zealand Standard**

**Ultrasonics—Fields—Guidance for the measurement and  
characterization of ultrasonic fields generated by medical ultrasonic  
equipment using hydrophones in the frequency range of  
0.5 MHz to 15 MHz**

**1 Scope**

This technical report provides guidance on the practical measurement of the acoustic output of various types of medical ultrasonic equipment in the frequency range 0,5 MHz to 15 MHz based on the use of hydrophones.

It gives simplified procedures and guidelines for the measurement of the acoustic output of medical ultrasonic equipment.

Procedures for correcting for limitations caused by the use of hydrophones with finite bandwidth and finite active element size are also given.

**2 Normative references**

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

IEC 1101: 1991, *The absolute calibration of hydrophones using the planar scanning technique in the frequency range 0,5 MHz to 15 MHz*

IEC 1102: 1991, *Measurement and characterization of ultrasonic fields using hydrophones in frequency range of 0,5 MHz to 15 MHz*  
*Amendment 1, Definitions of additional terms and specific requirements for the characterization of fields from ultrasonic transducers having cylindrical or spherical active elements (under consideration)*

IEC 1161: 1992, *Ultrasonic power measurement in liquids in the frequency range 0,5 MHz to 25 MHz*

**3 List of symbols**

|            |                                                         |
|------------|---------------------------------------------------------|
| $a_{\max}$ | Maximum effective radius of a hydrophone active element |
| $a_1$      | Effective radius of an ultrasonic transducer            |
| $C$        | Spatial-averaging correction factor                     |

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|                   |                                                                        |
|-------------------|------------------------------------------------------------------------|
| $I_{\text{spta}}$ | Spatial-peak temporal-average intensity                                |
| $I_{\text{sppa}}$ | Spatial-peak pulse-average intensity                                   |
| $l$               | Distance between a transducer and a measuring hydrophone               |
| $p_-$             | Peak-negative acoustic pressure                                        |
| $p_+$             | Peak-positive acoustic pressure                                        |
| $p_i$             | Pulse-pressure-squared integral                                        |
| $p_{\text{spr}}$  | Spatial-peak r.m.s. acoustic pressure                                  |
| $p_{\text{spp}}$  | Spatial-peak pulse acoustic pressure                                   |
| $p$               | Total ultrasonic power                                                 |
| $p_{\text{beam}}$ | Total power emitted by one acoustic scan line for an automatic scanner |
| $prr$             | Pulse repetition rate                                                  |
| $s_s$             | Separation between ultrasonic scan lines in the plane considered       |
| $t_d$             | Pulse duration                                                         |
| $\alpha$          | Ratio of the -6 dB beam-width to the effective hydrophone diameter     |
| $\sigma$          | Non-linear propagation parameter                                       |

## 4 Types of medical ultrasonic equipment

### 4.1 Pulse-echo and pulsed Doppler equipment

The acoustic output of pulse-echo diagnostic equipment usually consists of a single pulse of ultrasound at an acoustic working frequency in the range 1 MHz to 12 MHz, and at pulse repetition rates of between 1 kHz and 5 kHz. Pulsed Doppler equipment usually has an acoustic pulse consisting of a number of cycles at pulse repetition rates similar to or perhaps higher than pulse-echo equipment. In both types of equipment, the ultrasound is usually focused at distances from the transducer of between a few centimetres and 20 cm, and the peak acoustic pressure at the focus is usually between 0,2 MPa and 10 MPa. Whilst linear-array, sector and phased-array scanners emit consecutive pulses along different ultrasonic scan lines, the acoustic pulse waveform remains approximately constant.

For pulse-echo equipment, the focal diameter is usually less than about 3 mm and, as seen from 5.1, a hydrophone with an active element of diameter approximately 0,5 mm is required and a relatively precise alignment of the hydrophone is necessary. IEC 1102 specifies reproducibility of the positioning systems of  $\pm 0,01$  mm for three orthogonal adjustments for the hydrophone (or transducer if the latter is the item that is scanned). In practice, the accuracy and reproducibility of positioning systems is most important in the direction perpendicular to the propagation direction and in most cases  $\pm 0,05$  mm is often adequate. In the propagation direction, an accuracy of  $\pm 0,1$  mm is often adequate for most measurement situations. The highest accuracy would be required for highly focused fields (wide aperture) and at high frequencies (see 5.4).

As the acoustic pressures are high, the non-linear propagation parameter  $\sigma_m$  (see 3.25 of IEC 1102) will usually be greater than 0,5, in which case the bandwidth requirement for the hydrophone is greater and additional demands are placed on the angular alignment because of the dependence of this directional response on frequency. Under these conditions, it is important to optimise the rotation of the hydrophone to ensure the maximum received signal (see 5.3).

In general, diagnostic equipment places the greatest demand on the hydrophone bandwidth and on the coordinate positioning system. PVDF hydrophones of the membrane or probe type are essential (see A.1.4 of IEC 1102).

As measurements for the purpose of determining the maximum output are undertaken in the plane containing the spatial-peak temporal-peak acoustic pressure, this plane is expected to be close to the focus of the transducer. At typical focal distances, the square law relationship between acoustic pressure and intensity is usually assumed in order to derive intensity parameters. This assumption is made despite the uncertainty associated with the non-linear distortion that can take place.

#### 4.2 *Continuous-wave Doppler systems*

Frequencies for continuous-wave Doppler systems are usually between 2 MHz and 10 MHz, and an acoustic lens may be used to focus the ultrasound at distances from the transducer face of up to 8 cm. Peak acoustic pressures are usually less than 0,1 MPa and consequently the non-linear propagation parameter is generally below 0,5 and it is not necessary to use a broadband hydrophone. Focal diameters may be less than 3 mm and, as seen from 5.1, a hydrophone with an active element of diameter 0,5 mm or smaller is required. For the higher frequency devices, it may be necessary to rotate the hydrophone when measurements are made at distances from the acoustic axis greater than the transducer radius (see 5.3). In the case of foetal monitors, the acoustic beam is often divergent and the peak acoustic pressure usually occurs at the face of the ultrasonic transducer. Under these circumstances, the usual plane progressive wave approximation for ultrasonic intensity is invalid (see 8.2 of IEC 1102). Hence, only acoustic pressure parameters can be specified unless a compromise is made. Such a compromise is to undertake measurements in a plane which does not contain the spatial-peak temporal-peak acoustic pressure in the whole acoustic field and at a distance such that the plane progressive wave approximation for intensity may be assumed. Although not strictly appropriate for a focused ultrasonic field, the criterion given in reference [1]\* for a plane piston transducer may be used to estimate the difference between the true intensity and the intensity derived from the square of the acoustic pressure. A suitable compromise is to undertake measurements at a distance from the face of the ultrasonic transducer of between one and two ultrasonic transducer element diameters. For a plane piston transducer, this would yield errors of 4 % and < 2 % for these two cases.

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\* Figures in square brackets refer to the bibliography given in annex B.

PVDF or ceramic probe devices (see A.1.4 of IEC 1102) are satisfactory for measurements on continuous-wave Doppler transducers. Membrane hydrophones may be used providing care is taken to ensure the reflection from the membrane does not interfere with the output from the ultrasonic transducer (see 5.5).

Certain types of continuous-wave Doppler systems utilize ultrasonic transducers with cylindrical active elements and emit ultrasound radially. IEC 1102, amendment 1, provides the necessary guidelines for measurements which may be made on these systems.

#### 4.3 *Therapy transducers*

Ultrasonic transducers used for physiotherapy usually operate between 0,75 MHz and 3 MHz under continuous-wave or long tone burst excitation. Typically, the transducers have active elements of diameter 20 mm and may have an acoustic lens to provide focusing. Peak acoustic pressures are below 0,5 MPa with no significant non-linear distortion of the acoustic pressure waveform taking place in the near field of the transducer. Measurements can be made in any plane although it is usual to require them to be made in the near field. For measurements made at distances less than two transducer diameters there is the same problem of conversion from acoustic pressure to intensity as with the continuous-wave Doppler devices. Again, it is recommended that measurements are made at distances from the transducer which are greater than or equal to one transducer diameter. As the spatial-peak temporal-peak acoustic pressure occurs in the region of the last maximum in the axial pressure distribution, measurements may be made in planes at the following distances from the face of the ultrasonic transducer:

one transducer diameter;

two transducer diameters;

the distance corresponding to the plane containing the spatial-peak temporal-peak acoustic pressure.

The last measurement represents the spatial-peak temporal-peak acoustic pressure in the whole field whilst the first two measurements refer to a spatial-peak temporal-peak acoustic pressure in their respective planes. Here, and also if other measurement planes are used, it is important to specify the position of the measurement plane.

As seen from 5.1, the size of the active element of the hydrophone may be larger than that used for pulse-echo or continuous-wave Doppler ultrasonic transducers as the ultrasonic wavelength is usually larger; a device with an active element of diameter between 0,5 mm and 1 mm is usually acceptable. For such devices, the broad directional response of the hydrophone in this frequency range means it is unlikely that maximization of the received hydrophone signal by its rotation is necessary.