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Underwater acoustics — Quantities and procedures for description and measurement of underwater sound from ships —

Part 3: Requirements for measurements in shallow water

Grandeurs et modes de description et de mesurage de l'acoustique sous-marine des navires —

Partie 3: Exigences pour les mesurages en eau peu profonde

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 3, *Underwater acoustics*.

A list of all parts in the ISO 17208 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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Introduction

The ISO 17208 series describe procedures for the measurement and analysis of underwater sound from ships. The methodology and measurement configuration are sufficient to provide reliable acoustic data, but also suitable for end-users to conduct the measurements without access to large, fixed sound measurement facilities. ISO17208-1 covers measurements of radiated noise level in deep water, and ISO 17208-2 the calculation of source level from the deep-water data. This document has been developed to address the need to cover source level measurements in shallow water, one reason being that deep water maritime areas are sometimes far away from the zone of operation of the ships considered.

The development of this document was supported by the EU-funded Horizon 2020 research programme SATURN (Developing solutions to underwater radiated noise)[1)] and by the MMP2 project[2)], sponsored by Transport Canada's Innovation Centre.

1) https://doi.org/10.3030/101006443

2) https://doi.org/10.1121/10.0017433

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Underwater acoustics — Quantities and procedures for description and measurement of underwater sound from ships —

Part 3: Requirements for measurements in shallow water

1 Scope

ISO 17208 series describe procedures for the measurement of underwater sound radiated by the ship under test, and for calculating sound source quantities such as source level and radiated noise level from the measurement results.

In ISO 17208-1 to ISO 17208-3 it is presumed that the ship under test cooperates in the measurements, sailing multiple runs over a specified track past the measurement system at a specified speed with pre-determined machinery configurations. Opportunistic measurements of the radiated sound of passing ships are outside the scope of these three standards.

Part 1 of the ISO 17208 standards[1] provides the procedure to quantify the underwater sound from the ship in terms of its radiated noise level, which is calculated from the sound pressure level (SPL) measured in the far field of the ship, in beam aspect, scaled by the distance to CPA and reported in decidecade bands. The intended use of radiated noise level is to show compliance with contract requirements or criteria, for comparison of one ship to another ship, to enable periodic signature assessments, and for research and development.

ISO 17208-2[1] specifies methods for calculating the source level of an equivalent monopole source at a specified nominal source depth from the radiated noise level values obtained according to ISO 17208-1. The intended use of source level, with associated nominal source depth, is to perform far field sound predictions such as needed for environmental impact studies or for creating underwater sound contour maps.

ISO 17208-1 and ISO 17208-2[1] are applicable for measurements in deep water, defined as water depth greater than the larger of 150 m and 1,5 times overall ship length. The allowable water depths and environmental conditions for part 3 measurements are described in 4.5.

This document specifies procedures for the measurement of underwater sound radiated by the ship under test in shallow water. It also specifies procedures for the calculation of source level, with associated nominal source depth, from the sound pressure measurements, accounting for the relevant phenomena that govern the propagation of sound in shallow water. These calculations are described in Clause 7. Once the source level has been calculated, other metrics may be calculated from the source level and the source depth. 7.3 provides a procedure for calculating the radiated noise level that would have been measured in deep water according to ISO 17208-1 for the same ship with the same operating condition.

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 18405, *Underwater acoustics — Terminology*

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ISO 17208-1:2016, *Underwater acoustics — Quantities and procedures for description and measurement of underwater sound from ships — Part 1: Requirements for precision measurements in deep water used for comparison purposes*

IEC 60500, *Underwater acoustics - Hydrophones - Properties of hydrophones in the frequency range 1 Hz to 500 kHz*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 18405, IEC 60500 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

NOTE From ISO 18405, this includes the following terms: sound pressure, sound pressure level (SPL), propagation loss, source level, acoustic far field, decidecade. From IEC 60500, this includes the following terms: hydrophone, and sensitivity level.

3.1
shallow water
water of depth less than the larger of 150 m and 1,5 times the overall ship length

3.2
deep water
water of depth greater than the larger of 150 m and 1,5 times the overall ship length

3.3
overall ship length
longitudinal distance between the forward-most and aft-most part of a ship

3.4
acoustic ship length
L
user defined length L over which the ship is assumed to radiate the dominant sound over the frequency range of interest

Note 1 to entry: Dependent on the location of the dominant sound sources on the ship under test, this can be the overall ship length or the length of the aft part of the ship, where the propellers and the main engines are located.

3.5
ship reference point
position of the equivalent sound source representing the ship

Note 1 to entry: For the purpose of this part of ISO 17208, the ship reference point is located longitudinally at the centre of the *acoustic ship length* (3.4), transversely at the ship centre line and vertically at the nominal source depth.

Note 2 to entry: The position for the ship reference point applies for all frequencies.

3.6
nominal source depth
d_s
nominal depth below the sea surface of the monopole point source from which the sound is considered to originate, and equal to 0,7 times the ship's draught

Note 1 to entry: In formula form:

$$d_s = 0,7D$$

where D is the draught of the ship.

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Note 2 to entry: The draught of the ship is considered to be the average of the stern and bow draughts.

Note 3 to entry: The choice of the nominal source depth is somewhat arbitrary, and the choice of 70 % of the mean draught represents a compromise. The value of the nominal source depth is to be reported alongside the equivalent monopole beam aspect source level value.

3.7
closest point of approach
CPA
point at which the horizontal distance (during a test run) from the ship reference point of the ship under test to the hydrophone(s) reaches its minimum value

3.8
closest point of approach distance
CPA distance
d_{CPA}
horizontal distance (during a test run) from the ship reference point of the ship under test to the hydrophone(s) at its closest point of approach

3.9
beam aspect
aspect normal to ship centre line from bow to stern

Note 1 to entry: Beam aspect refers to the location of the hydrophone (s) with respect to the ship under test in port or starboard direction. For the purpose of ISO 17208, the beam aspect is measured over $\pm 30°$ data window angles.

3.10
data window angle
horizontal angle subtended at the hydrophone, between the start data location and the end data location

Note 1 to entry: The data window angle is expressed as a value in degrees as shown in Figure 1.

Note 2 to entry: The data window angle is ±30°.

3.11
data window length
DWL
l_{DW}
distance between the start data location and end data location

Note 1 to entry: The DWL is defined by the distance at closest point of approach and the data window angle of ±30° as given in Figure 1. In formula form:

$$l_{\mathrm{DW}} = 2\tan(30°)d_{\mathrm{CPA}}$$

where d_{CPA} is the CPA distance in metres.

3.12
data window period
DWP
t_{DW}
time it takes the ship under test to travel the data window length at a certain speed

Note 1 to entry: In formula form:

$$t_{\mathrm{DW}} = \frac{l_{\mathrm{DW}}}{v}$$

where l_{DW} is the data window length in metres and v is the ship speed in metres per second .

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3.13
nominal hydrophone angle
angle between the horizontal axis and the line created between the point at the sea surface above the ship reference point at CPA and the location of the hydrophone

Note 1 to entry: For the purpose of ISO 17208, for measurements at a CPA-distance smaller than the local water depth, the nominal hydrophone angles are 15°, 30° and 45° below the horizontal plane.

3.14
hydrophone cable drift angle
angle between the vertical axis and the line created between the fixed support of the hydrophone cable and the hydrophone

3.15
seabed critical angle
ψ_c
grazing angle in water below which sound waves are totally reflected at the seabed

Note 1 to entry: If the seabed is modelled as a fluid with speed of sound c_b, the critical angle is given by $\psi_c = \cos^{-1}(c_w / c_b)$, where c_w is the speed of sound in water.

3.16
measurement system
data acquisition system consisting of, but not limited to, one or more hydrophone(s), conditioning preamplifier(s), analogue-to-digital converter(s), computer and ancillary peripherals, or autonomous recorder combining the above functionality in one instrument

3.17
system sensitivity
quotient of the root-mean-square open-circuit output signal at a specified point in the measurement system (usually the electrical output terminals) to the incident root-mean-square sound pressure that would be present at the position of the reference centre of the hydrophone in the undisturbed free field if the hydrophone was removed for specified frequency and specified direction of plane wave sound

Note 1 to entry: The system sensitivity is defined here for an acoustic measurement system designed to measure sound pressure signals in water. The measurement system will typically consist of hydrophone(s) connected to amplifier(s) and filter(s) and will feed an output voltage into a digital acquisition and storage system. Note that the response of the hydrophone(s), amplifier(s) and filter(s) will in general vary with frequency.

Note 2 to entry: For an *analogue* system, the output signals are electrical voltages, and the sensitivity is described in terms of the electrical voltage developed per pascal of acoustic pressure, and is stated in units of V/Pa. The system sensitivity level can be expressed in decibels with reference to 1 V/µPa.

Note 3 to entry: For *digital* systems, the output is a digital waveform (rather than an analogue voltage output). Here, the calibration of the digitiser (analogue to digital converter) is incorporated into the overall sensitivity of the whole system. This is termed the *digital system sensitivity*, which is the number of digital counts per unit change in sound pressure (unit Pa^{-1}).

Note 4 to entry: In general, the measuring system may introduce a phase delay into the measured signal. This may be accounted for by representing the system sensitivity as a complex valued quantity, the modulus of which represents the magnitude-only response, and the phase of which describes the phase delay. For calculation of acoustic metrics which depend on the energy or power in the signal (e.g. SPL), the system phase response is of little significance.

Note 5 to entry: The system sensitivity is defined here as an acoustic free-field sensitivity using the free-field sensitivity of the hydrophone. If the hydrophone is physically attached on to another body such as an acoustic recorder or float (rather than deployed on an extension cable), diffraction and scattering of sound by the body may affect the free-field sensitivity at kilohertz frequencies, causing enhanced directivity compared to the response of the free hydrophone.

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3.18
calibration
method of using known inputs, possibly using physical stimuli (such as a known, calibrated and traceable acoustic source) or electrical input (charge or voltage signal injection) at the input (or other stage) of a measurement system

3.19
mean-square system-filtered sound pressure
$\overline{p'^2}$
integral over a specified time interval of squared weighted sound pressure, divided by the duration of the time interval, for a specified frequency range, when the linear filter is a specified underwater acoustic *measuring system* (3.16)

Note 1 to entry: Mean-square system-filtered sound pressure is expressed in pascals (Pa).

Note 2 to entry: See ISO (18405:2017), entry 3.7.1.1 *weighted sound pressure*.

3.20
mean-square system-filtered sound pressure level
$L_{p'}$
ten times the logarithm to the base 10 of the ratio of the *mean-square system-filtered sound pressure* (3.19) to the specified reference value, p_0^2, in decibels

Note 1 to entry: Mean-square sound pressure level is the level of the power quantity equal to the mean-square sound pressure, denoted p^2. In formula form, $L_{p'} = 10 \log_{10} \left(\overline{p'^2} / p_0^2 \right)$ dB.

Note 2 to entry: Mean-square sound pressure level is expressed in decibels (dB).

Note 3 to entry: In underwater acoustics, the reference value of mean-square sound pressure, p_0^2, is 1 μPa^2. The reference value shall be specified.

Note 4 to entry: The averaging time and frequency range shall be specified.

4 General measurement requirements

4.1 General

To perform a measurement of the sound radiated by a ship in shallow water, there are number of factors which need to be addressed, including selection of an appropriate test site, suitable deployment of hydrophones, appropriate choice of instrumentation, and proper operation of the vessel[3] under test. The following steps are to be followed:

4.2 Test ship parameters

a) The user selects the ship of interest, with a specified overall length and draught.

b) The user selects the configuration (propulsion power and machinery settings, with tolerance) to achieve the speed through the water for which the radiated sound is to be measured. Power and machinery operation should be held constant throughout repeat runs (5.4).

NOTE Ship radiated sound, particularly propeller cavitation noise, will be impacted to a varying degree by local wind and current effects, so speed over ground is not a suitable parameter.

c) The user defines the acoustic ship length L over which the ship is assumed to radiate the dominant sound. Dependent on the location of the dominant sound sources on the ship under test, this can be the

3) In the context of this standard the terms ‘ship’ and ‘vessel’ are used as synonyms.

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