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This draft standard is based on national and international discussions. Your comments on this draft are invited and will assist in the preparation of the consequent standard.

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Template for comments and secretariat observations

Date: xx/xx/20xx	Document: ISO/DIS xxxx
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1	2	(3)	4	5	(6)	7
MB	Clause No./ Subclause No./Annex (e.g. 3.1)	Paragraph/ Figure/Table/Note	Type of comment	Comment (justification for change) by the MB	Proposed change by the MB	Secretariat observations on each comment submitted
	3.1	Definition 1	ed	Definition is ambiguous and needs clarifying.	Amend to read '...so that the mains connector to which no connection...'	
	6.4	Paragraph 2	te	The use of the UV photometer as an alternative cannot be supported as serious problems have been encountered in its use in the UK.	Delete reference to UV photometer.	

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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

ICS: 17.140.30

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

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ISO 17208 was developed by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 3, *Underwater acoustics*.

ISO 17208 consists of the following parts, under the general title *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.

Part 2: Determination of source levels from deep water measurements.

Part 3: Requirements for measurements in shallow water.

Introduction

The ISO 17208 standards 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. Part 1 of the 17208 series covers measurements of radiated noise level in deep water, and Part 2 the calculation of source level from the deep-water data. The part 3 standard 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 the zone of operation of the ships considered.

The development of this standard was supported by the EU-funded Horizon 2020 research programme SATURN (Developing solutions to underwater radiated noise)¹⁾ and by the MMP2 project²⁾, sponsored by Transport Canada's Innovation Centre.

1) <https://www.saturnh2020.eu/>

2) <https://tcdocs.ingeniumcanada.org/sites/default/files/2021-08/Towards%20a%20Standard%20for%20Vessel%20Underwater%20Radiated%20Noise%20%28URN%29%20Measurement%20in%20Shallow%20Water.pdf>

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

Part 3: Requirements for measurements in shallow water

1 Scope

The ISO 17208 standards 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 17208 Parts 1 to 3 it is presumed that the ship under test cooperates in the measurements, sailing multiple runs along a specified track along 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 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.

Part 2 of the ISO 17208 standards 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 source depth, is to perform far field sound predictions such as needed for environmental impact studies or for creating underwater sound contour maps.

Parts 1 and 2 of ISO 17208 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 [Clause 4](#).

Part 3 of the ISO 17208 standards (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 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. Clause 7.4 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 in the same 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 18405:2017, *Underwater acoustics — Terminology*

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*

ISO 17208-2:2019, *Underwater acoustics — Quantities and procedures for description and measurement of underwater sound from ships — Part 2: Determination of source levels from deep water measurements*

ISO/IEC Guide 98-3:2008, *Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

3 Terms and definitions

3.1 General

For the purposes of this document, the terms and definitions given in ISO 18405, IEC 60500: 2017 and the following apply. From ISO 18405, this includes the following terms: sound pressure, sound pressure level (SPL), propagation loss, source level, acoustic centre, acoustic far-field, decidecade band. From IEC 60500, this includes the following terms: hydrophone, sensitivity level.

3.2 Definitions

3.2.1

shallow water

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

3.2.2

deep water

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

3.2.3

overall ship length

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

3.2.4

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 length of the ship or the length of the aft part of the ship, where the propellers and the main engines are located.

Note 2 to entry: For the purpose of this part of ISO 17208, it is required that the user selects an acoustic ship length that is greater than $1/3$ of the overall ship length.

3.2.5

ship reference point

point on the ship from which the distances are defined

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, transversely at the ship centre line and vertically at the nominal source depth.

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

3.2.6**(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 draft

Note 1 to entry: This depth is used for conversion of radiated noise level to equivalent monopole source level.

Note 2 to entry: In equation form:

$$d_s = 0,7D \quad (3.1)$$

where D is the draught of the ship.

Note 3 to entry: The draught of the ship is considered to be the average of the stern and bow draughts.

Note 4 to entry: The choice of the nominal source depth is somewhat arbitrary, and the choice of 70 % of the mean draft represents a compromise. The value of the nominal source depth is to be reported alongside the equivalent monopole beam aspect source level value.

3.2.7**closest point of approach****CPA**

point where the horizontal distance (during a test run) from the ship reference point of the ship under test to the hydrophone(s) is the smallest

3.2.8**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 $\pm 30^\circ$ data window angles.

3.2.9**data window angle**

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 $\pm 30^\circ$.

3.2.10**data window length****DWL** **l_{pw}**

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 $\pm 30^\circ$ as given in Figure 1

3.2.11**data window period****DWP** **t_{DWP}**

time it takes the ship under test to travel the data window length at a certain speed

Note 1 to entry: See [Formula \(6.1\)](#) in [Clause 6.2](#).

3.2.12

(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.

3.2.13

hydrophone cable drift angle

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

3.2.14

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

3.2.15

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 acoustic 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 is sometimes expressed in decibels as dB re 1 V/ μ Pa.

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 (eg 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.

[SOURCE: Adapted from ISO 18406:2017]

3.2.16

field calibration

method of using known inputs, possibly using physical stimuli (such as a known, calibrated and traceable acoustic or vibration source) or electrical input (charge or voltage signal injection) at the input (or other stage) of a measurement system in order to ascertain that the system is, in fact, responding properly (i.e. within the system's stated uncertainty) to the known stimulus

3.2.17**dynamic range**

the difference between the largest measurable mean-square sound pressure level, with a specified maximum allowable distortion, and the equivalent bandwidth noise pressure level, for a specified frequency band

Note 1 to entry: Dynamic range is expressed in decibels, dB.

[SOURCE: ISO 17208-1:2016]

3.2.18**equivalent bandwidth noise pressure**

p_w

quotient of the root-mean-square noise voltage at a specified central frequency in the relevant frequency band present at the electrical terminals of the hydrophone, in the absence of pressure fluctuations at the hydrophone input, and the modulus of its free-field receive sensitivity at a specified frequency

Note 1 to entry: Equivalent bandwidth noise pressure is expressed in pascals, Pa.

[SOURCE: adapted from ISO 18406:2017]

3.2.19**equivalent bandwidth noise pressure level**

ten times the logarithm to the base 10 of the ratio of the square of the value of equivalent bandwidth noise pressure, p_w , of a hydrophone to the square of a reference pressure, p_0 , in decibels

Note 1 to entry: In formula form $L_{EBNP} = 10 \log_{10} (p_w^2 / p_0^2)$ dB.

Note 2 to entry: Equivalent bandwidth noise pressure level is expressed in decibels, dB.

Note 3 to entry: The value of the reference pressure, p_0 , is 1 μ Pa.

[SOURCE: IEC 60500:2017]

3.2.20**signal-to-noise ratio**

ratio of the mean-square signal voltage in a specified frequency range after all processing to the mean-square noise voltage in the same specified frequency range after all processing

Note 1 to entry: The noise voltage is the voltage caused by non-acoustic noise and background noise.

Note 2 to entry: The time duration for the mean-square operation on the signal voltage and the background noise voltage shall be the same. This averaging time is specified with the value of signal-to-noise ratio.

Note 3 to entry: As a broadband quantity, the signal-to-noise ratio is evaluated over a specified frequency band. This may be the entire range of interest, which for this document is a minimum of 10 Hz to 20 kHz, or a specific frequency band such as a third-octave band. The applicable frequency band is stated with the value of the signal-to-noise ratio.

Note 4 to entry: The signal-to-noise ratio may be converted to a level difference, termed the signal-to-noise level difference, expressed in decibels.

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 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 draft.
- b) The user selects the configuration (machinery lay-out and propeller shaft rotation rate, or speed through water, or propulsion power) for which the radiated sound is to be measured.
- 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 overall length of the ship (from bow to stern) or the length of the aft part of the ship, where the propellers and the main engines are located. This length should be sufficiently larger than ship width and draft, hence it is required that length L is greater than $1/3$ of the overall length of the ship.
- d) The user defines ship reference point (transversely at the ship centre line, longitudinally at the centre of the selected length L , and vertically at the nominal source depth, i.e. at 0,7 times the ship's draft).

4.3 Frequency range

The user selects the frequency range of interest over which SL is required. Ideally the user follows ISO 17208-1, which specifies a minimum frequency range that covers the decade bands from 10 Hz to 20 000 Hz.

NOTE 1 Note that measurements at low acoustic frequencies are difficult in very shallow water where low frequency waves do not propagate. In addition, at such low acoustic frequencies, background noise, including platform-related deployment self-noise such as flow noise and cable strum, becomes more prevalent.

NOTE 2 Decade bands span one tenth of a decade and are also known as one-third octave (base 10) bands (ISO 18405).

4.4 CPA distance

Ship radiated sound measurements are to be made with hydrophone(s) located at a horizontal distance from the ship track, to measure the beam (starboard / port) aspect of the ship under test. The user selects a minimum horizontal closest-point-of-approach (CPA) distance between the ship track and the hydrophone location, that fulfils the following requirements:

- The hydrophone(s) shall be in the geometric far field of the ship under test, so that the ship can be described as a point source. Therefore, the CPA distance shall be greater than the acoustic ship length (see [Clause 4.2 c](#)).
- The hydrophone deployment shall not affect safe manoeuvring of the ship under tests.
- The maximum distance between hydrophone(s) and ship track at CPA shall be limited, to avoid signal-to-noise problems and to reduce uncertainty associated with propagation loss estimation (see [Clause 7](#)). It is advised to limit the CPA distance to a maximum of 5 times the local water depth.
- The minimum horizontal CPA distance for measuring small fast boats should be limited to achieve the minimum data window period that is needed for a reliable calculation of the SPL in the lowest frequency bands (see [Annex E](#)).

4.5 Test site selection

The user selects a measurement site, that fulfils the following requirements:

- Ideally, the water depth is larger than the CPA-distance ([Clause 4.4](#))
- If the water depth is much smaller than the CPA distance ([Clause 4.4](#)), the water depth and seabed properties should be such that the lowest frequency of interest is at or greater than the shallow

water cut-off frequency $f_{\min}$. The minimum depth $H_{\min}$ can be calculated from this equation, adapted from [Jensen et al, 2011, eq.(1.38)]:

$$H_{\min} = c_w / (4 f_{\min} \sin \psi_c) \quad (4.1)$$

where c_w is the speed of sound in water, c_b the speed of sound in the seabed and ψ_c the seabed critical angle $\psi_c = \cos^{-1}(c_w / c_b)$. Typical values for seabed parameters are provided in [Annex D](#).

NOTE 1 The user may consider adapting the lowest frequency of interest to the available water depth.

NOTE 2 The seabed properties here refer to the upper sediment layer. Sediment layers, particularly where soft sediment overlays a hard substrate or where the seabed contains gaseous layers, can have a substantial influence on sound propagation. Sites with such properties are to be avoided where possible.

NOTE 3 For example, a 'medium sand' seabed, with $c_b / c_w = 1,2$ has a critical angle $\psi_c = 33^\circ$ and requires a water depth of 77 m for the cut-off frequency (8,8 Hz) to be below the lower limit of the 10 Hz decade band (8,91 Hz).

- The water depth should be uniform over the area that covers the ship track length over which the ship radiated sound is measured (see [Clause 4.3](#)) as well as the hydrophone locations, to within 10 %.
- The speed of sound in the seabed (see Note 2 above) in this area should be uniform to within 10 %. A sandy seabed is preferred, to avoid immersion of bottom mounted hydrophones in soft sediment.
- The user should be aware that shallow water effects can affect ship resistance and hence have influence on the ship radiated sound. ISO 15016: 2015 (Ships and marine technology — Guidelines for the assessment of speed and power performance by analysis of speed trial data) suggests that ship resistance for a ship of width B [m] and draft T [m] at speed V [m/s] is affected if the water depth is smaller than the larger of the values obtained from the two equations: $H_{\min} = 3\sqrt{BT}$ and $H_{\min} = (0,3 \text{ s}^2 / \text{m}) \cdot V^2$.
- The background noise at the test site should be low enough to permit measurement of the underwater sound of the ship under test over the frequency range of interest. That means that the background noise in the area (including the sound from ships passing at distance from the measurements site) should be at least 10 dB below the sound from the ship under test.

4.6 Acoustic measuring instrumentation

The measuring system generally consists of the following instruments: hydrophone(s); amplifier(s) and signal conditioning equipment; digitization and storage equipment.

The amplifier can be a separate element in the system with an adjustable gain, or may be an integral part of the hydrophone with no possibility for gain adjustment. Digitization is provided by an analogue to digital converter (ADC) and the electronic storage is typically provided by a computer hard drive or flash drive memory.

4.6.1 System sensitivity

The sensitivity of the measuring system should be chosen to be an appropriate value for the amplitude of the sound being measured. The aim in the choice of the system sensitivity is to avoid a poor signal-to-noise ratio for low amplitude signals.

NOTE 1 To build in some flexibility, it is preferable to have some selectable gain in the amplification stages, or in the settings of the ADC. These can then be set to appropriate values once the sound levels are known after some initial measurements. However, note that for autonomous recorders and hydrophones which have integral preamplifiers, the gain cannot usually be modified after deployment.

NOTE 2 Ideally the same hydrophone and gain settings are used for the background noise measurements and the measurement of the sound radiated from the vessel under test. A hydrophone with low-noise performance and high sensitivity is generally preferred.

NOTE 3 If extra cable is added to a hydrophone which does not have an integral preamplifier, this will reduce the overall sensitivity for the hydrophone due to the extra electrical loading caused by the capacitance of the extension cable. Either the hydrophone is calibrated with the extension cable connected, or the effect of the electrical loading is calculated [IEC 60565-1]. For hydrophones that have an integral preamplifier within the hydrophone body, adding extension cable will not affect the sensitivity.

NOTE 3 Hydrophones with integral amplifiers have either differential or single ended outputs. It is important to ensure that hydrophone, cable and receiver are configured consistently, and calibration is performed for the same configuration.

4.6.2 Frequency range and sampling rate

The measuring system shall record sound pressures over the desired frequency range (as specified in [Clause 4.3](#)). This requires that the hydrophone, and any amplifier and filter, be sufficiently broadband.

NOTE 1 The requirement for unambiguous representation of the signals within the desired frequency range requires the sampling rate, f_s , of the ADC within the recording system to be greater than the Nyquist rate of the signal which is input to the ADC. Where the measured data are to be represented in decidecade bands, the maximum frequency of interest will be the upper limit of the maximum decidecade frequency band of interest.

NOTE 2 It is desirable that the system sensitivity be invariant with frequency over the frequency range of interest (i.e. that it possess a “flat response”), to within a tolerance of 2 dB. Note that it is possible to correct for the variation in the sensitivity with frequency with better accuracy than the above tolerance if the hydrophone and measuring system is calibrated over the full frequency range of interest.

NOTE 4 For analysis in broad frequency bands (for example decidecade or one tenth decade bands), the instrumentation must be capable of covering the lower and upper limits of the lower and upper frequency bands respectively.

4.6.3 Directivity

The hydrophone (or hydrophone and recorder) used shall have an omnidirectional response such that its sensitivity is invariant with the direction of the incoming sound wave to within a tolerance of 2 dB over the frequency range of interest.

NOTE 1 This requirement is not difficult to satisfy at frequencies up to 20 kHz in the XY (horizontal) plane, and for the majority of the XZ and YZ (vertical) planes of the hydrophone response [IEC 60500], which defines the angular range of significance for the hydrophone. For angles of incidence close to the body or cable of the hydrophone (or body of the recorder), the directivity is likely to show greater variation due to shielding of the hydrophone element. When deploying the hydrophone or recorder, care should be taken not to orient the device to minimize this shielding effect. One issue that can cause enhanced directionality is where the hydrophone is deployed close to another structure that is capable of reflecting the sound waves. This effect can be evident at kilohertz frequencies if the hydrophone is deployed close to a support structure such as a heavy mooring or support, or a recorder case that houses electronics and batteries but is mostly air-filled. Similarly, if the hydrophone has a guard deployed around it, this can influence the directivity at kilohertz frequencies. If necessary, the above effects can be quantified by directional response measurements of the hydrophone together with the mounting, in a free-field environment.

4.6.4 System self-noise

To achieve acceptable signal-to-noise ratio when measuring acoustic signals, the system self-noise (expressed as the equivalent bandwidth noise pressure level) shall be at least 10 dB below the lowest