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Acoustics — Measurement of airborne sound emitted by vessels on inland waterways and harbours

Acoustique — Mesurage du bruit aérien émis par les bateaux de navigation intérieure et portuaire

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ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.ch
Web www.iso.ch

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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 3.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 2922 was prepared by Technical Committee ISO/TC 43, *Acoustics*, Subcommittee SC 1, *Noise*.

This second edition cancels and replaces the first edition (ISO 2922:1975), which has been technically revised.

Acoustics — Measurement of airborne sound emitted by vessels on inland waterways and harbours

1 Scope

This International Standard specifies the conditions for obtaining reproducible and comparable measurement results of the airborne sound emitted by vessels of all kinds on inland waterways and in ports and harbours, except powered recreational craft as specified in ISO 14509. This International Standard is applicable to small sea-going vessels, harbour vessels, dredgers, and all watercraft including non-displacement craft, used or capable of being used as a means of transport on water.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

IEC 60942, *Electroacoustics — Sound calibrators*.

IEC 61260, *Electroacoustics — Octave-band and fractional-octave-band filters*.

IEC 61672-1, *Electroacoustics — Sound level meters — Part 1: Specifications*.[1)]

3 Terms and definitions

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

3.1
acceptance test for vessels
acceptance test
measurement performed to prove that the sound emitted by the vessel, stationary or in motion, as delivered by the manufacturer, complies with noise specifications or prescribed limits

3.2
monitoring test for vessels
monitoring test
measurement performed in order to check that the sound emitted by the vessel, stationary or in motion, is still within prescribed limits and that no noticeable changes have occurred since the acceptance on initial delivery or after modification, as applicable

1) To be published. (Revision of IEC 60651 and IEC 60804)

3.3
maximum AS-weighted sound pressure level for vessels
maximum AS-weighted sound pressure level
$L_{p\mathrm{ASmax}}$
maximum sound pressure level achieved from measurement during the passage of the vessel under specified operating conditions measured with frequency weighting A and with time weighting S according to IEC 61672-1

NOTE It is expressed in decibels (dB).

3.4
A-weighted sound exposure
E_{A}
time integral of squared, instantaneous, A-weighted sound pressure over a stated time interval or event

NOTE 1 It is expressed in pascal-squared seconds ($\mathrm{Pa^2 \cdot s}$).

NOTE 2 In symbols, the A-weighted sound exposure, E_{A}, of a specified event (e.g. the passage of a craft) is represented by

$$E_{\mathrm{A}} = \int_{t_1}^{t_2} p_{\mathrm{A}}^2(t)\,\mathrm{d}t$$

where $p_{\mathrm{A}}^2(t)$ is the squared, instantaneous, A-weighted sound pressure as a function of running time t for an integration time starting at t_1 and ending at t_2 (see 11.1.1).

3.5
A-weighted sound exposure level
L_{AE}
ten times the logarithm to the base 10 of the ratio of an A-weighted sound exposure, E_{A}, to the reference sound exposure, E_0, given by the product of the square of the reference sound pressure of $p_0 = 20\ \mu\mathrm{Pa}$ and the sound exposure reference duration of $T_0 = 1$ s, ($E_0 = p_0^2 \cdot T_0 = 4 \times 10^{-10}\ \mathrm{Pa^2 \cdot s}$)

NOTE 1 It is expressed in decibels (dB).

NOTE 2 In symbols, the A-weighted sound exposure level, L_{AE}, of a specified event (e.g. the passage of a vessel) with the duration $T = t_2 - t_1$, is related to a corresponding measurement of the time-averaged A-weighted sound pressure level, $L_{p\mathrm{Aeq},T}$, by

$$L_{\mathrm{AE}} = 10\ \mathrm{lg}\left\{\frac{\left[\int_{t_1}^{t_2} p_{\mathrm{A}}^2(t)\,\mathrm{d}t\right]}{p_0^2 T_0}\right\}\mathrm{dB} = 10\ \mathrm{lg}\left(\frac{E_{\mathrm{A}}}{E_0}\right)\mathrm{dB} = L_{p\mathrm{Aeq},T} + 10\ \mathrm{lg}\left(\frac{T}{T_0}\right)\mathrm{dB}$$

where $p_{\mathrm{A}}^2(t)$ is the squared, instantaneous, A-weighted sound pressure as a function of running time t.

NOTE 3 The A-weighted sound exposure level L_{AE} is arithmetically identical to the single-event sound pressure level $L_{p,1\mathrm{s}}$ (reference duration $T_0 = 1$ s) as, for example, defined in ISO 3744.

NOTE 4 The abbreviation "SEL" is sometimes used for the single-event sound pressure level, $L_{p,1\mathrm{s}}$.

NOTE 5 In this International Standard, the sound exposure level is to characterize the emission of the source and not the noise impact on people exposed to the sound.

3.6
background noise for vessels
background noise
noise from all sources other than the craft under test

EXAMPLE Noise from waves splashing on the measuring craft or the shore, other craft or equipment, and wind effects.

4 Measurement quantities

4.1 Frequency weighting A shall be used for all measurements.

4.2 Care should be taken to avoid any influence on the result from unwanted sound signals, for example noise from wind on the microphone of the measuring equipment, electrical interference, or extraneous sound sources not under consideration.

4.3 The quantities to be determined at all microphone positions in acceptance and monitoring tests are the A-weighted sound exposure level, L_{AE}, received from the operation of vessel and the maximum AS-weighted sound pressure level, $L_{p\mathrm{ASmax}}$, both expressed in decibels.

4.4 If, in addition to the sound exposure level, spectral analysis in acceptance tests or determination of some special acoustical characteristics of vessels is needed, the quantities to be measured are the unweighted or C-frequency weighted, octave-band or one-third-octave-band S-time weighted sound pressure levels in decibels at the time of maximum sound pressure, or the unweighted or C-frequency weighted, octave-band or one-third-octave-band sound exposure levels in decibels.

4.5 When measurements are made at some distance from the source, the levels observed may be considerably affected by the weather conditions. For example, the attenuation of sound due to air absorption is affected by the temperature and humidity of the air. In addition the refraction of sound waves due to wind and temperature gradients will affect the levels received at a particular position. It is recommended that measurements taken in extreme or atypical conditions be avoided. If possible, a value obtained under typical climatic conditions, and an indication of the range of values obtained under other climatic conditions, should be included in the test report.

4.6 For steady-state noise, as that from a stationary ship's engine, the quantity to be measured is the time-averaged A-weighted sound pressure level, $L_{p\mathrm{Aeq}}$.

5 Measurement uncertainty

Table 1 lists the likely sources of uncertainty and estimates of the standard deviation associated with each based on experience. These sources of uncertainty are considered to be independent for each measurement type. Therefore, the estimated total standard uncertainty is given by the square root of the sum of the squares of the individual standard deviations contained in Table 1.

Table 1 — Standard deviation of reproducibility

Values in decibels

Individual sources of uncertainty	Individual standard deviations			
	Maximum AS-weighted sound pressure level L_{ASmax}	**A-weighted sound exposure level** L_{AE}	**Time-averaged A-weighted sound pressure level at 25 m** L_{pAeq}	**Time-averaged A-weighted sound pressure level at 1 m** L_{pAeq}
Distance effects	0,25	0,15	0,0	1,0
Measuring equipment	1,0	0,7	0,7	0,7
Sound propagation conditions	1,5	1,2	1,2	0,0
Waves, currents and tides	1,5	1,5	0,0	0,0
Operator(s) effects	0,2	0,2	0,1	0,1
Test site variations	1,0	1,0	1,5	1,0
Operating conditions	0,5	0,5	0,5	0,5
Estimated total standard uncertainty	2,6	2,3	2,1	1,7

6 Measuring equipment

6.1 Equipment specifications

The instrumentation system, including microphones and cables (which shall be used according to the manufacturer's specifications), and including the windscreen recommended by the manufacturer and the overall electroacoustic performance of any additional measuring equipment, including for example a tape recorder and/or level recorder, shall meet the requirements for a type 1 instrument specified in IEC 61672-1.

NOTE Sound level meters with "maximum hold" capabilities are preferred to measure the maximum S-time weighted sound pressure level.

When a tape recorder is used for the measurements, the dynamic range of the instrumentation shall be consistent with the measured signal.

For the measurement of noise spectra the filters shall correspond to IEC 61260, class 1.

A wind speed anemometer which is accurate to within ± 10 % shall be used.

An engine speed tachometer which is accurate to within ± 50 r/min shall be used.

6.2 Windscreen

A suitable windscreen shall be used to reduce the influence of wind on the reading. When it can be expected that the wind-induced signal will be within 10 dB of the average sound level induced by the vessel under investigation, windscreens shall be used which, together with the sound level meter, meet the requirements of IEC 61672-1.

6.3 Equipment calibration

A sound calibrator which meets the requirements of IEC 60942 shall be used.

The overall acoustic performance of the measurement equipment shall be checked with the sound calibrator, according to the manufacturer's instructions, at the beginning and at the end of each series of measurements and at least at the beginning and end of each measurement day.

At intervals of no longer than 2 years, the sound level meter shall undergo laboratory verification for compliance with IEC 61672-1. The date of the last verification of the compliance with IEC 61672-1 shall be recorded.

The sound calibrator used for calibration of the sound level meter shall undergo laboratory verification every year, with traceability to a primary standards laboratory.

7 Test site specifications and environmental conditions

7.1 Test conditions

Two classes of test conditions are considered, namely

— when the vessel is under way, the requirements of 7.2.1, 7.3 and 7.4 shall apply;

— when the vessel is alongside a wharf or at anchor, the requirements of 7.2.2, 7.3, 7.4 and 7.5 shall apply.

7.2 Test site specifications

7.2.1 Moving vessels

Within 30 m around the vessel under test and the microphone, there shall be no large surfaces (e.g. retaining walls, building façades, rocks, bridges) from which sound can be reflected back to the microphone.

In the vicinity of the microphone, there shall be no obstacles which could disturb the sound field. Therefore, no person shall be between the microphone and the sound source, and any observers shall be in such a position that any influence on the meter reading is avoided.

The area between the vessel under test and the measurement microphone shall be open water, free from any sound absorbing or sound reflecting objects.

7.2.2 Stationary vessels

The surroundings of the microphone up to 30 m shall be free of large, sound-reflecting objects like barriers, hills, rocks, bridges or buildings.

7.3 Environmental conditions

7.3.1 At wind velocities above 7 m/s, the sound propagation may be disturbed and measurements shall not be performed.

7.3.2 Tests shall be avoided in conditions of rain or other precipitation and/or when wave motion or surf is too high for the size of vessel under test.

7.4 Background noise

7.4.1 Acceptance tests

The maximum AS-weighted sound pressure level, the A-weighted sound exposure level and/or the time-averaged sound pressure level due to other noise sources (e.g. waves splashing on the measuring boat or ashore, other vessels, local industry or other machinery) and due to wind shall be at least 10 dB below the maximum AS-weighted sound pressure level, the A-weighted sound exposure level and/or the time-averaged sound pressure level of the sound of the vessel.

If the noise is frequency analysed, the difference shall be at least 10 dB in the required octave or one-third-octave bands.

7.4.2 Monitoring tests

7.4.2.1 Correction for $L_{p\mathrm{ASmax}}$ and for $L_{p\mathrm{Aeq}}$

The $L_{p\mathrm{ASmax}}$ and/or the $L_{p\mathrm{Aeq}}$ of the background noise shall be at least 6 dB below the corresponding reading obtained during the passage of the vessel (for $L_{p\mathrm{ASmax}}$) and/or during the measurment period (for $L_{p\mathrm{Aeq}}$). The readings shall then be corrected according to Table 2.

7.4.2.2 Correction for L_{AE}

The L_{AE} of the background noise is given in terms of the background $L_{p\mathrm{Aeq}}$:

$$L_{\mathrm{AE\ (back)}} = L_{p\mathrm{Aeq\ (back)}} + 10 \lg (T/1\mathrm{s})\ \mathrm{dB}$$

where T is the integration time used to calculate for L_{AE}.

The L_{AE} of the background noise shall be at least 6 dB below the corresponding reading obtained during the passage of the vessel. The reading shall then be corrected according to Table 2.

Table 2 — Correction for background sound pressure level, $L_{p\mathrm{AS}}$, for monitoring tests

Values in decibels

Difference between the maximum AS-weighted sound pressure level, the A-weighted sound exposure level[a] and/or the A-weighted time-averaged sound pressure level[b] and the corresponding quantities for the background noise	Correction to be applied to the reading of the maximum AS-weighted sound pressure level, the A-weighted sound exposure level[a] and/or the A-weighted time-averaged sound pressure level[b]
⩾ 10	0
6 to 9	– 1

[a] Both obtained during the passage of the vessel.

[b] Obtained during the measurement period.

7.5 Measurements on stationary vessels

For tests taken when the vessel is moored or alongside a wharf or fitting-out basin, etc., it may be impossible to obtain a distance of 30 m from large reflecting surfaces. Where this occurs, details on the test location shall be included in the report.

NOTE 1 Measurements taken at a specific location in such conditions will refer only to that particular location and no correlation should necessarily be inferred for noise measurement taken at another berth.

NOTE 2 The sound from moored vessels measured on land could be significantly affected by the form of the wharf to which the vessel is moored. High, solid wharves could provide considerable shielding to an extent governed by, say the state of the tide.

8 Test course and measurement of distance

8.1 At the test course, the depth of water shall be sufficient for normal operation of the vessel.

8.2 During the test, the course of the vessel shall be as straight as possible at the distance from the microphone specified in clause 10.

8.3 Vessels being tested on inland waterways shall run either against the current or tide or in slack water. However, as specified in 11.1.2 the noisier side shall be measured.

NOTE This requirement may necessitate waiting for a suitable tide.

8.4 The distance between the microphone and the side of the vessel shall be measured with an accuracy of ± 1 m by optical means, for example by range-finders or photographic techniques, unless this distance is measured by running the vessel on a prescribed course past a microphone placed in a prescribed position. In this latter case, permanent test sites with appropriate direction markers are recommended.

9 Operating conditions

9.1 Distance from microphone

The test run shall start at a sufficient distance from the microphone to obtain stabilized engine conditions when passing the microphone, with the vessel proceeding against any current or tide.

9.2 Loading condition

The loading condition of the vessel, the quantity, type and stowage of cargo, as well as the draught of the vessel, shall be stated in the test report. For small craft, the disposition of masses, including the number and seating of persons, shall be recorded. For acceptance tests, the vessel shall be at minimum loading.

9.3 Main engines

9.3.1 During the tests, the main engines shall run at 95 % or more of their rated speed or at a nominal number of revolutions of the propellers according to the specifications in the contract clauses for the vessel's acceptance or, in the case of a commissioned vessel, at the maximum continuous rate of engine revolutions.

9.3.2 For a stationary vessel, with measurements at selected places, the propulsion machinery shall be stopped if this is normal for harbour conditions.

9.4 Auxiliary engines

All auxiliary engines and equipment necessary for continuous service and normal operation shall run at their normal speed and normal load.

9.5 Doors and windows

During acceptance tests, measurements shall first be performed with windows and doors of the engine rooms shut. The sound pressure level with the windows and doors of the engine rooms open shall be stated separately.

9.6 Monitoring tests

During monitoring tests, the vessel shall run under normal sailing conditions. Windows and doors of the engine rooms shall be open if this is usual during normal operating conditions.

10 Microphone position

10.1 The microphone shall be positioned at 3,5 m ± 0,5 m above the water surface and, if mounted on a solid surface, shall be positioned at least 1,2 m above that surface. The microphone shall be positioned within ± 0,5 m of the edge of the surface above which it is mounted.

10.2 When the vessel passes the microphone, the distance between the side of the vessel and the microphone shall be 25 m ± 5 m.

NOTE Depending on the directivity of sound radiation, the highest indication of the sound level meter might not occur when the vessel is at its closest point. For this reading the distance might be more than 25 m.

10.3 If the point of closest approach between the microphone and the vessel deviates from the reference distance of 25 m, the results shall be corrected according to 11.1.4.

10.4 For the measurement of sound emitted by vessels at anchor, such as dredgers, salvage vessels, diving vessels, the microphones shall be placed 25 m ± 2 m from the side and at several points around the vessel. Machinery on board the vessel shall be run at the normal speed used when the vessel is at anchor or working and with normal load.

10.5 When measuring the sound pressure levels at the intake and exhaust of the engine or the air-conditioning and cooling system, it is recommended that the microphone be placed outside the gas stream at a distance of 1 m from the edge of the intake or exhaust opening, at an angle of 30° to the direction of the gas stream, and as far as possible from reflecting surfaces.

11 Test procedure

11.1 Moving vessels

11.1.1 Measure the sound exposure level of each individual pass-by from the time at which the sound of the approaching vessel is first heard above the background noise until the time that the sound from the departing vessel fades into the background noise. The maximum AS-weighted sound pressure level indicated during the passage of the vessel shall also be measured. For this latter measurement, ignore any maximum level which is obviously out of character with the general sound pressure level being read.

NOTE In practice the exact start and finish of the sound exposure level measurement is not critical provided that the measurement period covers the highest 10 dB of the sound from the passage of the vessel.

11.1.2 For acceptance tests, make at least two passages. Round the sound exposure levels and the arithmetic mean value of the sound pressure level to the nearest integral decibel.

If the sound radiation of the vessel is obviously asymmetrical with respect to the longitudinal axis of the vessel, then measurement shall be performed at the side with the higher sound pressure level.

The spread between the results of sound exposure measurements made during the two passages shall not be larger than 3 dB, otherwise a new series of measurements shall be made.

11.1.3 For monitoring tests, slight deviation from the test conditions specified for acceptance tests may be tolerated with respect to the test site, the background noise, the distance between the microphone and the vessel, and the operating conditions. For example, the number of measurement positions and the number of engine operating conditions may be reduced.

11.1.4 If the distance d between the microphone and the side of the vessel at its closest approach deviates from the reference value of 25 m, the A-weighted sound exposure level, $L_{AE,d}$, measured at a distance d and the maximum AS-weighted sound pressure level, $L_{pASmax,d}$, measured at a distance d shall be corrected according to the following relationship to obtain the A-weighted sound exposure level, $L_{AE,25}$, for the reference distance 25 m and the maximum AS-weighted sound pressure level, $L_{ASmax,25}$, for the reference distance 25 m:

$$L_{AE,25} = L_{AE,d} + k \lg [d/(25\text{m})] \text{ dB}$$