Guide for the Classification Notation

Underwater Noise and External Airborne Noise

April 2024

GUIDE FOR THE CLASSIFICATION NOTATION

UNDERWATER NOISE AND EXTERNAL AIRBORNE NOISE
APRIL 2024

American Bureau of Shipping
Incorporated by Act of Legislature of
the State of New York 1862

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Foreword *(1 April 2024)*

This Guide sets forth requirements for the following optional notations:

- Underwater noise: **UWN (Type)** and **UWN+ (Type)**
- External airborne noise: **AIRN, AIRN+** and **AIRN-M (a, b)**.

The underwater noise notations **UWN (Type)** and **UWN+ (Type)** are applicable to self-propelled commercial and research vessels. The external airborne noise notations **AIRN**, **AIRN+** and **AIRN-M (a, b)** are applicable to all types of vessels. This Guide outlines the process and requirement to obtain these notations. It provides criteria on noise limits and requirements for measurement method and measurement data post-processing.

For underwater noise emissions, the IMO and the European Union (EU) have made efforts to support the reduction of underwater radiated noise. IMO MEPC.1/Circ.833 *Guidelines for the Reduction of Underwater Noise from Commercial Shipping to Address Adverse Impacts on Marine Life* and EU Marine Strategic Framework Directive, 2008/56/EC address concerns about underwater noise pollution affecting marine life and habitats.

For external airborne noise emission, many ports have raised concerns about the noise pollution in port surroundings. Excessive ship external airborne noise disturbs residents living near ports and lowers the environmental quality of port areas.

This Guide is developed in response to the increasing demand to reduce ship noise emissions for better environmental quality.

The July 2022 version relocated survey after construction requirements from the Guide into the ABS *Rules for Survey After Construction (Part 7)* and replaced them with references to Part 7. Requirements for initial surveys were also added.

The April 2024 version clarifies that the background noise data is to be collected in accordance with 5/13.5, not during the data window period (DWP).

This Guide becomes effective on the first day of the month of publication.

Users are advised to check periodically on the ABS website www.eagle.org to verify that this version of this Guide is the most current.

We welcome your feedback. Comments or suggestions can be sent electronically by email to rsd@eagle.org.

GUIDE FOR THE CLASSIFICATION NOTATION

UNDERWATER NOISE AND EXTERNAL AIRBORNE NOISE

CONTENTS

SECTION 1
General

1 Introduction *(1 May 2021)*

The impact of underwater ship noise on marine life as a result of the global increase of vessel numbers, vessel size, and propulsion power has recently become an emerging issue in the marine industry. Ships generate underwater noise over a broad range of low frequencies, particularly from the propeller, machinery, and hull movements. The radiated underwater noise poses a potential threat to marine mammal behavior and/or induces stress responses as it may interfere with their hearing of natural signals for communication, feeding, socializing, prey detection, and orientation in the water.

Historically, underwater radiated noise from commercial vessels was not a key area of consideration in ship design and construction. However, efforts have been made by international regulatory bodies such as IMO and the EU to minimize the adverse effect of underwater radiated noise from commercial vessels on marine mammals (see, for instance, IMO MEPC.1/Circ.833; EU MSFD 2008/56/EC).

Noise emitted by vessels to the surrounding environment is becoming a concern in many port areas, especially those close to residential areas. Noise sources on vessels, such as engine ventilation, can be loud and travel significant distances. Around-the-clock operation of vessels berthed at the port also poses an additional challenge, since the emitted airborne noise causes nighttime disturbance of nearby residents. All these can have a negative impact on the well-being and health of the residents living in the proximity of a port.

It is suggested to perform noise analysis in the design stage as fixing excessive noise issues after construction would be difficult and expensive.

This Guide is developed to provide optional notations for underwater radiated noise and external airborne noise to promote vessel design and operation that reduce environmental impact.

3 Application *(1 May 2021)*

This ABS *Guide for the Classification Notations Underwater Noise and External Airborne Noise* is applicable to vessels for which one or multiple optional underwater noise notations and/or external airborne noise notations listed below have been requested.

UWN (Type)	For the vessel that has met the underwater noise criteria specified in this Guide. See Subsection 3/3 and Subsection 3/5.
UWN+ (Type)	For the vessel that has met the more stringent underwater noise criteria specified in this Guide. See Subsection 3/7.

Type denotes the type of underwater noise criteria. The following **Type** notations may be assigned:

T	Underwater noise criteria for Transit condition. See Subsection 3/3 and Subsection 3/7.
Q	Underwater noise criteria for Quiet Operation condition. See Subsection 3/3 and Subsection 3/7.
R	Underwater noise criteria for Research Vessels. See Subsection 3/5.

AIRN	For the vessel that has met the external airborne noise criteria specified in this Guide as confirmed by measurement. See Section 6 and Section 7.
AIRN+	For the vessel that has met the more stringent external airborne noise criteria specified in this Guide as confirmed by measurement. See Section 6 and Section 7.
AIRN-M (a, b)	For the vessel that had its external airborne noise measured in accordance with the measurement procedure as specified in Section 7. **a** denotes the averaged A-weighted external airborne noise level (31.5 to 8000 Hz) of the vessel under normal berth condition, in dB(A). **b** denotes the averaged A-weighted external airborne noise level of the vessel in low frequency range (31.5 to 160 Hz) under normal berth condition, in dB(A).

A commercial vessel may carry multiple underwater noise notations. The notation **UWN (T)** and/or **UWN (Q)** can be assigned provided the vessel can meet the underwater noise criteria under Transit condition for normal operation and/or Quiet Operation condition for low speed operation in environmentally-sensitive areas. The minimum vessel speed in the test for the Quiet Operation condition is specified in 5/11.1. When the vessel can meet more stringent underwater noise criteria, notation **UWN+ (T)** and/or **UWN+ (Q)** can be assigned. For research vessels, there is only one underwater noise notation, **UWN (R)**.

The underwater noise notations are applicable to self-propelled commercial vessels and research vessels that are equipped with ship acoustic design technologies in their design and construction to perform specific operations. The application of the underwater noise notations to offshore exploration and production vessels is subject to case-by-case review by ABS with consideration of specific designs and operational conditions of these vessels. The underwater noise notation only focuses on the noise aspect generated during normal/routine ship activities. Other marine activities, such as seismic surveys or pile driving, which result in loud and short duration noise, are not covered in the scope of this Guide.

The external airborne noise notations **AIRN**, **AIRN+** and **AIRN-M (a, b)** can be applied to all types of vessels.

5 Scope *(1 May 2021)*

This Guide outlines the process and criteria to obtain the underwater noise notation and external airborne noise notation. It provides requirements on acoustic instrumentation, test site conditions, measurement procedures for the underwater noise measurement and external airborne noise measurement. It also provides a description of post-processing of the measurement data.

7 Process of Obtaining a Notation *(1 May 2021)*

The flowchart in Section 1/ Figure 1 depicts the process for obtaining the underwater noise notation and/or the external airborne noise notation defined in this Guide.

7.1 Process for the UWN Notations *(1 May 2021)*

An underwater noise measurement plan together with the required information indicated in 2/1.1 is to be submitted to ABS for review and approval before commencing the underwater noise measurement. The information to be included in the underwater noise measurement plan is indicated in 2/3.1. The underwater noise measurement and the data collection are to be executed by an ABS Service Supplier and witnessed by an ABS Surveyor. The requirements for becoming an ABS Service Supplier for Underwater Noise Measurement can be obtained from the ABS Programs Office or the local ABS office. The ABS Surveyor accepts the underwater noise measurement data, provided the measurement meets the applicable requirements specified in this Section 4 and 5. The original underwater noise measurement data sheet (see

Appendix 1) is to be retained for ABS's files. The ABS Service Supplier is to post-process the collected measurement data and include processed results in a final underwater noise measurement report. The detailed requirements for the underwater noise measurement report are indicated in 2/5.1. The final measurement report is to be submitted to ABS for review.

The **UWN (Type)** or **UWN+ (Type)** notation may be issued provided that:

- The underwater noise measurement has been carried out according to the measurement plan approved by ABS and the procedures as specified in Section 5, and
- The resulting signature noise source level from the measurement is within the maximum allowable underwater noise level criteria limits as per Section 3.

7.3 Process for the AIRN Notations *(1 May 2021)*

An external airborne noise measurement plan together with the required information indicated in 2/1.3 is to be submitted to ABS for review and approval before commencing the external airborne noise measurement. The information to be included in the external airborne noise measurement plan is indicated in 2/3.3. The external airborne noise measurement and the data collection are to be executed by an ABS Service Supplier and witnessed by an ABS Surveyor. The requirements for becoming an ABS Service Supplier for External Airborne Noise Measurement can be obtained from the ABS Programs Office or the local ABS office. The ABS Surveyor accepts the external airborne noise measurement data, provided the measurement meets the applicable requirements specified in this Section 7. The original external airborne noise measurement data sheet (see Appendix 2) is to be retained for ABS's files. The ABS Service Supplier is to post-process the collected measurement data and include processed results in a final external airborne noise measurement report. The detailed requirements for the external airborne noise measurement report are indicated in 2/5.3. The final measurement report is to be submitted to ABS for review.

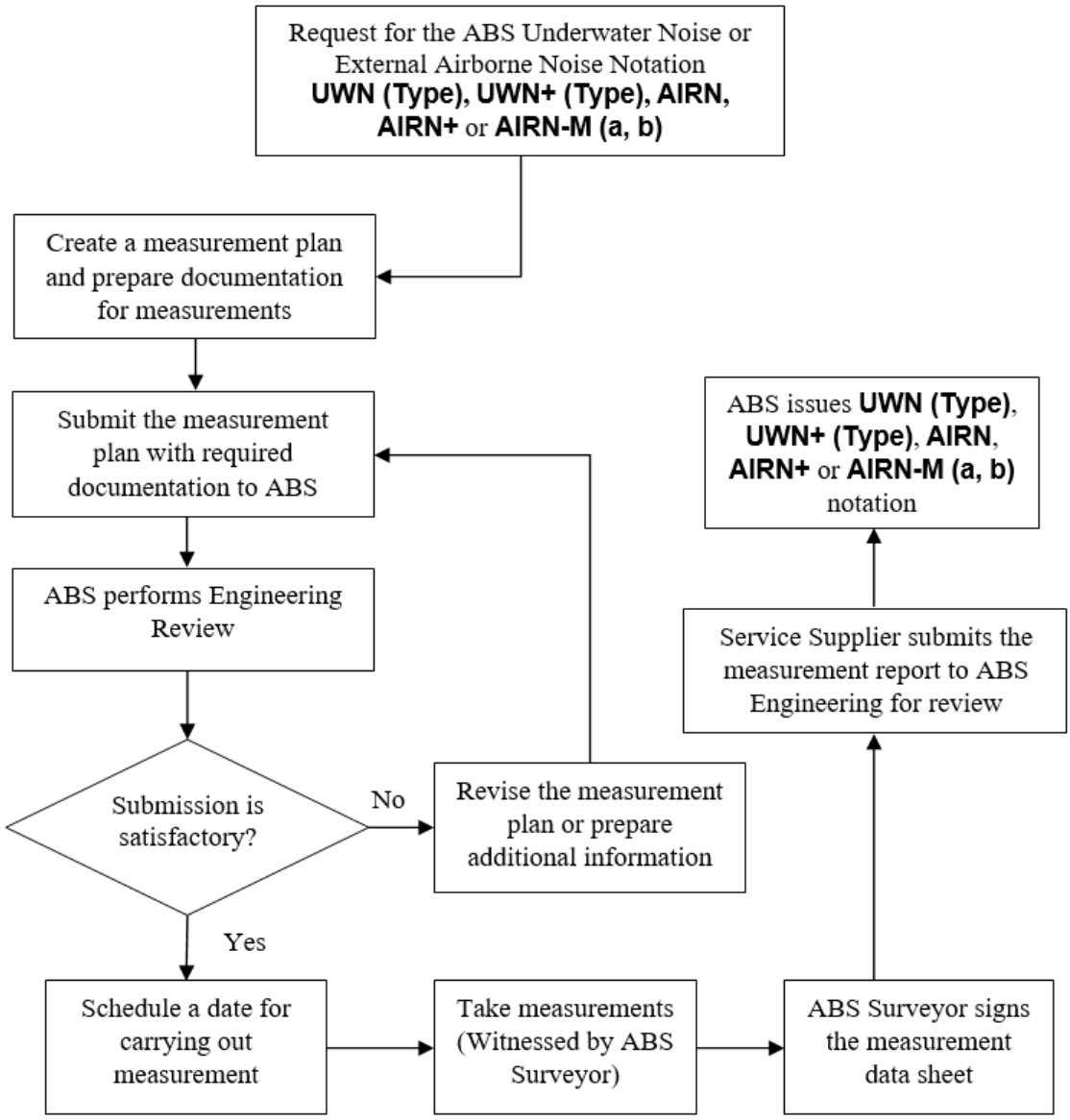
The **AIRN** or **AIRN+** notation may be issued provided that:

- The external airborne noise measurement has been carried out according to the measurement plan approved by ABS and the procedures as specified in Section 7, and
- The final noise level of the vessel is within the maximum allowable external airborne noise criteria limits as per Section 6.

The **AIRN-M (a, b)** notation may be issued provided that:

- The external airborne noise measurement has been carried out according to the measurement plan approved by ABS and the procedures as specified in Section 7.

FIGURE 1
Flow Diagram for Obtaining ABS Underwater Noise Notation and/or External Airborne Noise Notation



9 Alternatives *(1 May 2021)*

ABS is prepared to consider alternative procedures, methods or arrangements that are based on internationally recognized codes/standards. When alternate codes and/or standards are proposed, comparative analyses are to be provided to demonstrate equivalency to the criteria in this Guide.

11 Major Modifications *(1 May 2021)*

For the underwater noise notations, ABS is to be notified of any modifications made to major components on the vessel, such as changes to the hull form, the main machinery (including propulsion and large auxiliary equipment) and propellers, which contribute to the underwater radiated noise.

For the external airborne noise notations, ABS is to be notified of any modifications made to engine exhaust arrangements and ventilation systems, as well as the equipment operating on open deck such as cargo cranes and oil pumps, which contribute to the external airborne noise.

ABS will review the scope of the modification and advise the shipyard/owner of the necessity for a new set of measurements to be carried out in accordance to Section 5 and/or Section 7 of this Guide in order to maintain the existing notation.

12 Surveys After Construction *(1 July 2022)*

See Section 7-9-47 of the ABS *Rules for Survey After Construction (Part 7)*.

13 Definitions *(1 May 2021)*

Acoustic Center. The position on the vessel where it is assumed that all the noise sources are co-located as a single point source. In this Guide, it is assumed to be located halfway between the center of the engine room and the propeller for all test conditions.

Attenuation. The opposite of amplification, which is necessary when voltages to be digitized are beyond the analog-to-digital converter (ADC) range. This form of signal conditioning decreases the input signal amplitude so that the conditioned signal is within the ADC range. Attenuation is typically necessary when measuring voltages that are more than 10 volts.

Background Noise. Noise from all sources (biotic and abiotic) other than the vessel being tested and measured.

Beam Aspect. The direction to either side of the vessel under side.

Broadband. In the context of this Guide, "broadband" refers to sound energy over the one-third octave frequency band. In order to compare broadband measurements, the underwater acoustics community generally report broadband levels in one-third octave frequency bands.

Cavitation Inception Speed. Vessel speed at which a propeller starts to cavitate.

Closest Point of Approach (CPA). The point during a test run where the horizontal distance from the acoustic center of the vessel under test is the closest to the hydrophone(s). This position on the straight line course is referred as the CPA point. The distance at the closest point of approach is defined by the symbol d_{CPA}. See Section 5/ Figure 1.

Data Window Length (DWL). The distance between the start data point and the end data point, given as $2 \times d_{CPA} \times \tan(30)$. See Section 5/ Figure 1.

Data Window Period (DWP). The time window the test vessel to travel the data window length (DWL) at a specified test speed (v) given by $DWP = DWL/v$.

Decibel (dB). A relative unit for the intensity of a sound wave to a reference intensity. For underwater sound, it is expressed using the logarithmic decibel scale referenced to 1 micro-Pascal, as dB re 1 µPa (1.45×10^{-10} psi). For airborne sound, it is expressed using the logarithmic decibel scale referenced to 20 micro-Pascal, as dB re 20 µPa (2.9×10^{-9} psi).

Effective Sound Pressure. The root mean square of the sound pressure of the source over a given interval of time or space.

End Data Point. The position where the data recording is ended when the acoustic center of the test vessel passed this point. It is typically at a distance half DWL past the CPA point. This point is also known as the "Stern CPA". See Section 5/ Figure 1.

Ending Point of Test Range. The ending location of a test run at a distance twice the data window length (DWL) after the CPA point. See Section 5/ Figure 1.

Equivalent Continuous A-weighted Sound Pressure Level (L_{Aeq}). Average A-weighted sound pressure level over a period of time. A-weighted sound pressure level is the magnitude of a sound, expressed in decibels (i.e., 20 µPa); the various frequency components are adjusted according to the A-weighted values given in IEC 61672.1 in order to account for the frequency response characteristics of the human ear. The unit is dB(A).

Far Field. A region in free space, away from the sound source. In this region, the sound pressure is in phase with the sound particle velocity. In the far field, the direct field radiated by most machinery sources will decay at the rate of 6 dB each time the distance from the source is doubled.

Free Field. A sound field region where sound may propagate freely without any form of obstruction. In practice, a free field can be said to exist if the direct sound is 6 dB, or preferably 10 dB, greater than the reverberant or reflected sound.

Hydrophone. A transducer that produces electric signals in response to water borne acoustic signals. For the purpose of this Guide, “hydrophone” could also refer to the underwater microphone or electro-acoustic transducer.

Narrow Band. The entire frequency range is divided into subsections with equal bandwidth. The bandwidth is usually 1 Hz.

Near Field. A part in the sound field region which is close to a source where the sound pressure is not in phase with the sound particle velocity. In this region, the sound field does not decrease by 6 dB each time the distance from the source is increased (as it does in the far field). The near field is limited to a distance from the source equal to about a wavelength of sound or equal to three times the largest dimension of the sound source (whichever is the larger).

Normal Berth Condition. Normal vessel operation condition when berthed in port. Equipment and systems that normally operate under the vessel berth condition are to operate in normal condition.

Omni-directional Hydrophone. Underwater sound pressure transducer that responds equally to sound from all directions.

One-third Octave Band. The logarithmic frequency band whose upper limit is $2^{1/3}$ (1.26) times the lower limit, and the center frequency is the geometric mean of the upper and lower frequency limits. In underwater sound applications, the sound source spectrums are usually represented in the one-third octave bands. The standard one-third octave band center frequencies are defined as: 10, 12.5, 16, 20, 25, 31.5, 40, 50, 63, 80 Hz, and factors of 10 times and 100 times of this list of frequencies, and so on.

Pistonphone. An apparatus having a rigid piston which can be given a reciprocating motion of a known frequency and amplitude, so as to permit the establishment of a known sound pressure in a closed chamber of small dimensions (Ref: IEC 60565). Also, an acoustical calibrator (sound source) that uses a closed coupling volume to generate a precise sound pressure for the calibration of measurement microphones. It is to be calibrated using a calibrated microphone if the results are to be traceable.

Quiet Operation Condition. A low-speed operation condition for a vessel operating in environmentally-sensitive areas. The minimum vessel speed in the test for the Quiet Operation is specified in 5/11.1.

Radiated Noise. A vessel’s radiated noise is the acoustic energy radiated into the sea by sources originating at or within the vessel, from machinery transmitted to the hull/water interface, machinery and flow noise through sea-connected piping systems, and hydrodynamic noise caused by the interaction of the ship hull.

Sheet Cavitation. Sheet cavitation is a kind of propeller cavitation. It is generated due to large suction pressures build up near the leading edge of the blades when the blade sections are working at non-shock-free angles of incidence.

Sound Pressure Level (SPL) (or Sound Level (Lp)). A logarithm measure of the effective sound pressure of a sound relative a reference value. It is measured in decibels (dB) above a standard reference level where p_{rms} is the root-mean-square sound pressure measured and p_{ref} is the reference sound pressure. In water, a reference level of one 1 µPa (1.45×10^{-10} psi) is used. In air, a reference level of one 20 µPa (2.9×10^{-9} psi) is used.

$$L_p = 10\log\left(\frac{p_{rms}^2}{p_{ref}^2}\right) = 20\log\left(\frac{p_{rms}}{p_{ref}}\right)$$

Source Level. The apparent strength of a sound source at a nominal reference distance of one meter (3.28 feet) from the source and expressed in dB re 1 µPa (1.45×10^{-10} psi) in underwater acoustics.

Start Data Point. The position where the data recording is started when the acoustic center reaches this point. It is typically at a distance half DWL ahead of the CPA point. This point is also known as the "Bow CPA". See Section 5/ Figure 1.

Starting Point of Test Range. The starting location of a test run at a distance twice the data window length (DWL) ahead of the CPA point. See Section 5/ Figure 1.

Tip Vortex Cavitation. Tip vortex cavitation is a kind of propeller cavitation generated from the low-pressure core of the shed vortices. It usually occurs at the blade tips.

Transmission Loss (TL). A measure of the rate of loss in intensity or pressure of the acoustic field strength as sound propagates from a source to a receptor.

15 Abbreviations

ADC: Analog-to-digital converter

CPA: Closest point of approach

DAS: Data acquisition system

DWL: Data window length

DWP: Data window period

EU: European Union

GES: Good Environmental Status

GPS: Global positioning system

ICES: International Council for the Exploration of the Sea

IMO: International Maritime Organization

MCR: Maximum continuous rating

MEPC: Marine Environmental Protection Committee

MSFD: Marine Strategic Framework Directive

SECTION 2

Plans and Documentation to be Submitted

1 Plans and Documentation for Information

1.1 Underwater Noise *(1 May 2021)*

Where applying for an underwater noise notation, the following vessel plans are to be submitted to the ABS Engineering Office for information:

- General arrangement drawings with vessel main particulars such as overall length, draft, etc.
- Machinery information: manufacturer, model, power, RPM, etc.
- Propeller information: manufacturer, model, propeller diameter, propeller pitch, number of blades, speed, power, etc.

1.3 External Airborne Noise *(1 May 2021)*

Where applying for an external airborne noise notation, the following vessel plans are to be submitted to the ABS Engineering Office for information:

- General arrangement drawings with vessel main particulars such as overall length, draft, etc.
- Ventilation arrangement of accomodation, hull space and engine room
- Engine exhaust layout and insulation plan
- Arrangement of machinery equipment on open deck
- List and specifications of equipment operating during measurement.

3 Measurement Plan *(1 May 2021)*

Before commencing the underwater noise or external airborne noise measurement during trials, the measurement plan is to be submitted to ABS for review and approval. The review of the measurement plan serves as a primary means of verification of the compliance with requirements and conditions for carrying out the underwater noise or external airborne noise measurement during trials.

3.1 Underwater Noise

The underwater noise measurement plan is to include:

i) Vessel Information and Identification of Participants

- ***a)*** Vessel information, including vessel's name, hull number, class number, as well as the vessel's main dimensions
- ***b)*** Identification of participants, including person in charge of test, owner representative, shipyard representative, test personnel, and ABS Surveyor

ii) Measurement Test Site

a) Geographical location, water depth and sea bottom conditions

b) Wind speed and sea surface conditions for planned tests

c) Acceptable range of weather that the measurement may be carried out

iii) Measurement System

a) Hydrophones (number, type, and model) and deployment (method and hydrophone depths, including sketches to show the deployment configuration)

b) Distance measurement system

c) Calibration plans and current calibration certificates of all measurement instruments

d) Detailed information of data acquisition and recording system to be used

iv) Sea Test

a) Description of measurement procedure

b) Propeller operating rotational speed and load on engines and generators

c) Test agenda, including test schedules, a description of the planned test courses (including sketches to show the sailing course and identification of the closest point of approach (CPA), and various starting and ending points) and the operating profile which includes the speed and loading condition of the test vessel for each test course

d) Methods to be used for monitoring the test site environment, checking the vessel operation conditions, and other auxiliary measurements

v) Post Processing/Analysis

a) Description of post processing and analysis procedures of measured underwater sound data

b) Methods for evaluating the measurement uncertainty

3.3 External Airborne Noise

The external airborne noise measurement plan is to include:

i) Vessel Information and Identification of Participants

a) Vessel information, including vessel's name, hull number, class number, as well as the vessel's main dimensions

b) Identification of participants, including person in charge of test, owner representative, shipyard representative, test personnel, and ABS Surveyor

ii) Measurement Instruments

a) Details of sound level meter, wind screen, field calibrator, and distance measurement system (e.g., manufacturer, type and serial number, accuracy, sampling frequency and resolution)

b) Calibration plans and current calibration certificates of sound level meter and field calibrator

iii) Test Condition

a) Details of the location of the test site

b) Acceptable range of weather conditions including wind speed, and sea surface conditions that the measurement may be carried out

c) Machinery and equipment operation condition such as load on auxiliary engines

iv) Measurement Method to be used

a) Indication of the measurement method to be used (far field measurement method and/or individual source measurement method)

v) Measurement Location - Far Field Measurement Method

a) Location of measurement points where the measurement will be taken

b) Details of measurement positions

vi) Noise Source Measurement – Individual Source Measurement Method

a) List of noise sources to be measured

b) Measurement standards to be used for measuring the sound power level of each noise source

vii) Data acquisition and analysis

a) Information regarding the methods, software, and instrumentation to be used for data acquisition and analysis.

5 Measurement Report *(1 May 2021)*

After completing the measurements and results post-processing, the final noise measurement report is to be submitted to ABS for review.

5.1 Underwater Noise *(1 May 2021)*

The underwater noise measurement report is to include:

i) Measurement details

a) Verification of the details in measurement plan

b) All deviations from the approved Measurement Plan are to be reported

c) Any indications of abnormal activity during the test that might skew results

ii) Measurement results

a) Background, distance, and other auxiliary noise measurement results

b) One-third octave band measurement results for each hydrophone and each test run

iii) Post-Processing

a) Data quality assessment

b) Background noise correction

c) Sensitivity adjustment

d) Distance normalization

e) Average of measurement results

f) Verification of measurement results against criteria

g) Narrow band analysis (optional)

5.3 External Airborne Noise *(1 May 2021)*

The external airborne noise measurement report is to include:

i) Measurement details

a) Verification of the details in measurement plan

b) All deviations from the approved Measurement Plan are to be reported

c) Any indications of abnormal activity during the test that might skew results

ii) Measurement equipment details

a) Details of measurement and data analysis equipment (e.g., manufacturer, type and serial number, accuracy, sampling frequency and resolution)

b) Copies of the relevant instrumentation reference calibration certificates, together with the results of field setup and calibration checks

iii) Measurement method

a) Method used for the measurement (i.e., far field measurement method and/or individual source measurement method)

iv) Measurement results

a) Far field measurement method

- Details of measurement points and measurement positions
- Measurement duration
- L_{Aeq} and octave band measurement results (31.5 to 8000 Hz) of each measurement point
- L_{Aeq} and octave band measurement results of background noise

b) Individual source measurement method

- Details of the sound power level measurement for each noise source (measurement standard used, measurement duration, measurement location, etc.)
- Octave band (31.5 to 8000 Hz) measured sound power level of each noise source

v) Post-Processing

a) Far field measurement method

- Background noise correction
- Distance Correction
- Average of measurement results

b) Individual source measurement method

- Details of analysis method used to calculate the sound pressure level 100 meters (328 feet) away from the vessel (details of the noise models, standard used for the calculation, directivity correction of sources if any, etc.)
- Averaged calculated sound pressure level 100 meters (328 feet) away from the vessel

SECTION 3

Underwater Noise Requirements

1 General *(1 May 2021)*

This Section specifies the requirements for the maximum allowable underwater noise limits for specific operating conditions. The type of criteria is assigned with the **Type** notation as specified in Subsection 1/3.

The frequency range to be evaluated is between 10 Hz to 50,000 Hz for commercial vessels and 10 Hz to 100,000 Hz for research vessels.

Allowable limits are expressed in one-third octave bands. The unit of the sound pressure level limit is 1 µPa @ 1 m (1.45×10^{-10} psi @ 3.28 ft) in this Guide. It means that the sound pressure level is to be evaluated at 1 m (3.28 ft) away from the acoustic center of the vessel, and the reference sound pressure is 1 µPa (1.45×10^{-10} psi).

Compliance with the Guide is to be verified through underwater sound measurements.

A maximum 3 dB in excess of the criteria curve at a single one-third octave band is acceptable if the overall measured noise level of the vessel can meet the criteria specified in this Guide.

Deviations from the requirements, if they can be justified by analysis, may be accepted upon assessment by ABS (for example, if the narrow band analysis shows the deviations at low frequencies are not related to the underwater noise source, but from disturbance of the measuring device due to sea surface effect or from interference of another object, such as a metrological sound buoy).

3 Underwater Noise (UWN) Requirements for Commercial Vessels *(1 May 2021)*

The maximum allowable UWN limits for commercial vessels in one-third ($^1/_3$) octave bands are specified in Section 3/ Figure 1 and the formulae of the limits are provided in Section 3/ Table 1.

FIGURE 1
Allowable UWN Limits for Commercial Vessels

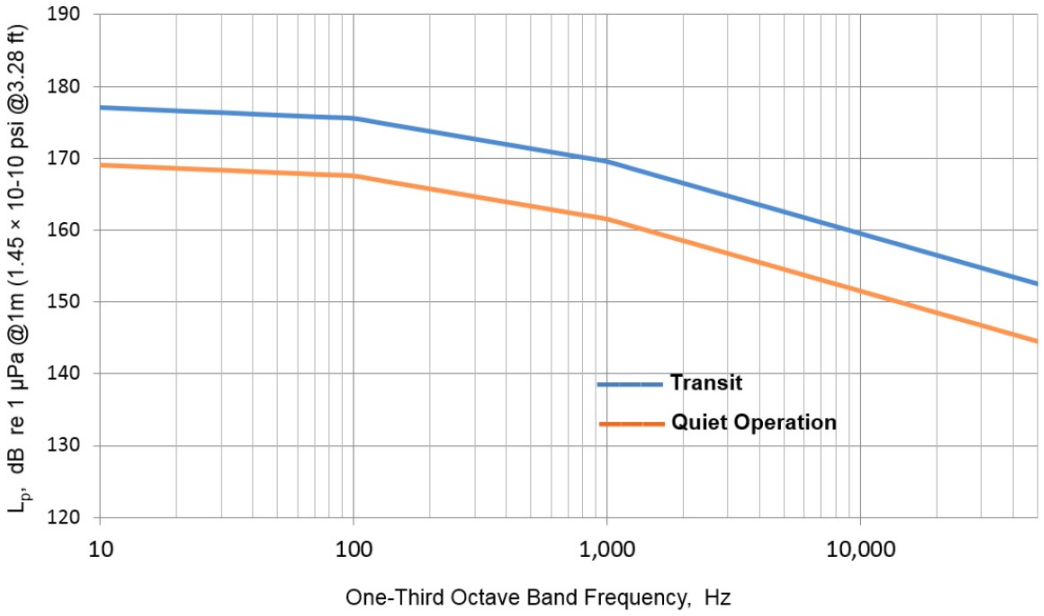


TABLE 1
UWN Limits for Commercial Vessels

Frequency Range	*Criteria, Lp, in dB re 1 µPa @1 m (1.45 × 10^{-10} psi @ 3.28 ft)*	
	Transit Condition	*Quiet Operation Condition*
10 – 100 Hz	–1.5 log f + 178.5	–1.5 log f + 170.5
100 – 1 k Hz	–6 log f + 187.5	–6 log f + 179.5
1 k – 50 k Hz	–10 log f + 199.5	–10 log f + 191.5

5 Underwater Noise (UWN) Requirements for Research Vessels

The maximum allowable UWN limits in one-third ($^1/_3$) octave bands for research vessels are given in Section 3/ Figure 2 and Section 3/ Table 2, which are based on the International Council for the Exploration of the Sea (ICES) 209 standard for all free running speeds from 0 knot to 11 knots.

FIGURE 2
Allowable UWN Limits for Research Vessels

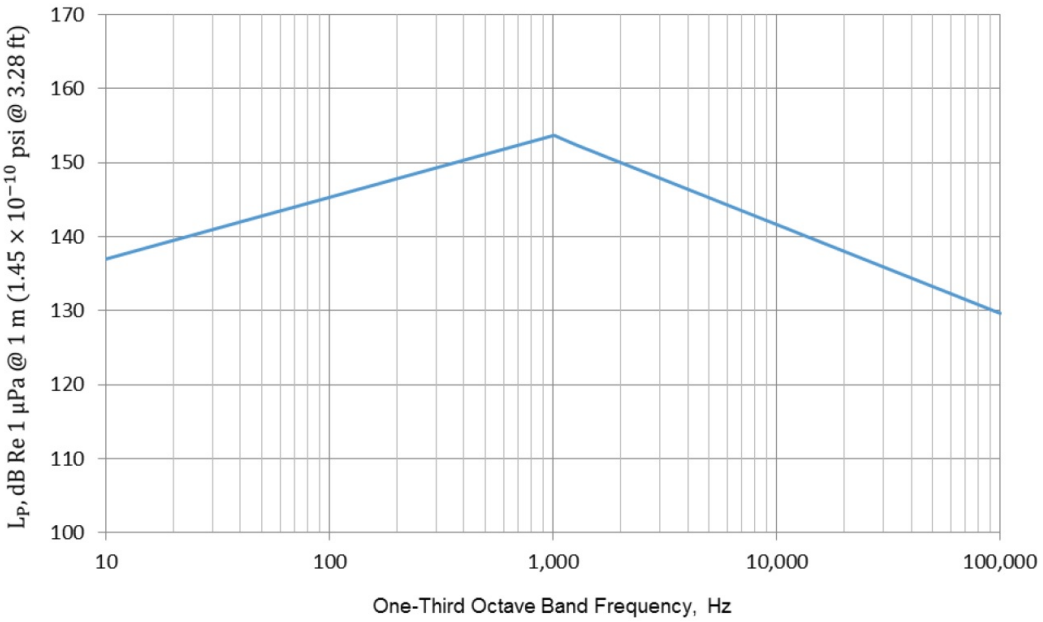


TABLE 2
UWN Limits for Research Vessels

Frequency Range	*Criteria, Lp, in dB re 1 µPa @1 m (1.45 × 10^{-10} psi @ 3.28 ft)*
10 – 1k Hz	135 – 1.66 log f + 10 log(Δf), f in Hz
1 k – 100 k Hz	130 – 22 log f + 10 log(Δf), f in kHz

where Δf is the bandwidth of the measured data.

7 Underwater Noise Plus (UWN+) Requirements for Commercial Vessels *(1 May 2021)*

The maximum allowable limits for the **UWN+ (Type)** notation for commercial vessels in one-third ($^1/_3$) octave bands are specified in Section 3/ Figure 3, and the formulae are given in Section 3/ Table 3.

FIGURE 3
Allowable UWN+ Limits for Commercial Vessels

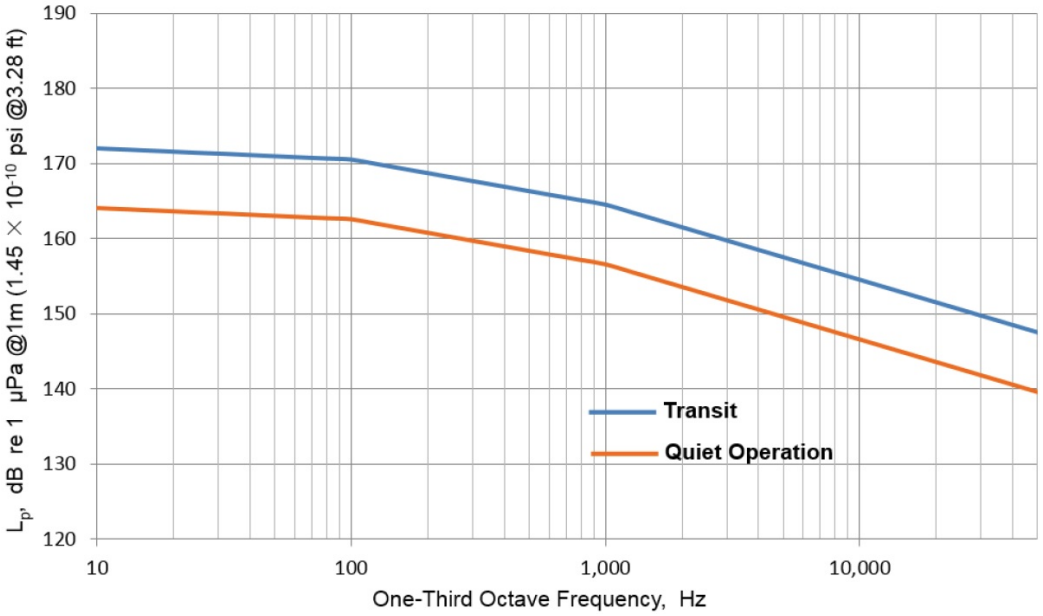


TABLE 3
UWN+ Limits for Commercial Vessels

Frequency Range	*Criteria, Lp, in dB re 1 µPa @1 m (1.45 × 10^{-10} psi @ 3.28 ft)*	
	Transit Condition	*Quiet Operation Condition*
10 – 100 Hz	–1.5 log f + 173.5	–1.5 log f + 165.5
100 – 1 k Hz	–6 log f + 182.5	–6 log f + 174.5
1 k – 50 k Hz	–10 log f + 194.5	–10 log f + 186.5

SECTION 4

Instrumentation for Underwater Noise Measurement *(1 May 2021)*

1 Introduction *(1 May 2021)*

This Section outlines the instrumentation requirements for measurement of the underwater sound emitted by vessels for the assignment of the **UWN (Type)** or **UWN+ (Type)** notation.

The key instrumentation components that are used for the measurement of underwater noise include:

i) Hydrophones and their signal conditioning

ii) Sound data acquisition and recording systems

iii) Sound data processing and display systems

"Hydrophone" as used in this Guide refers also to an underwater microphone or electroacoustic transducer.

3 Hydrophones and Signal Conditioning

3.1 Required Characteristics of a Hydrophone *(1 May 2021)*

The selected hydrophones that are used to measure the vessel under test are to meet the performance standard as described in Section 4/ Table 1.

TABLE 1
Performance Requirements of Hydrophones *(1 May 2021)*

Item	*Specification*
Number and Type of Hydrophones	At least three omni-directional hydrophones
Hydrophone Sensitivity (Uncertainty)	3 dB (If deviates, the client could submit their assessment of uncertainty based on the recommendation by the instrument manufacturer)
Frequency Span	10 Hz to 50,000 Hz for commercial vessels; 10 Hz to 100,000 Hz for research vessels
Calibration	• Portable Arrangement: Laboratory calibration every 12 months as well as field calibrated prior to and daily throughout the measurement series. • Fixed Arrangement: Laboratory calibration before installation. Field calibration prior to and daily throughout the measurement series.

The calibration of the hydrophones is to comply with IEC 60565-1 and IEC 60565-2, or ANSI S1.20.

3.3 Deployment of Hydrophones *(1 May 2021)*

Proper deployment of the hydrophone(s) is necessary for the accurate measurement of underwater noise levels of the vessel.

The hydrophones could be deployed by means of a surface-supported system, such as a floating line system from a support vessel, or by utilizing a surface buoy. Other acceptable means include a bottom-mounted system, which involves an anchor with submerged buoy. Section 4/ Figures 1 through 3 show the different hydrophone deployment configurations for the underwater noise measurement.

For the underwater noise measurement conducted in shallow water (see 5/9.1), the hydrophones are to be deployed by bottom mounted system.

To reduce the measurement uncertainties which could occur due to factors such as surface wave action on the vessel hull and noise generated from the vessel engines, deployment of hydrophones using either the bottom mounted system (Section 4/ Figure 3) or the floating line system such as a surface buoy with independent recorders (Section 4/ Figure 2) are preferred over the deployment method using a support vessel.

For more accurate measurement results, multiple hydrophones are encouraged to be deployed.

3.3.1 Floating Line Deployment using Surface Supported System

i) *Surface Buoy.* The use of the surface buoy aids to create a stand-off distance from the support vessel. This is useful in minimizing wave slap on the hull.

ii) *Suspension Device.* This decouples the surface motion from the hydrophone and recorder.

iii) *Retrieval Ropes.* These help retrieve the wires and hydrophones once the measurements have been carried out.

FIGURE 1
Deployment Using a Support Vessel

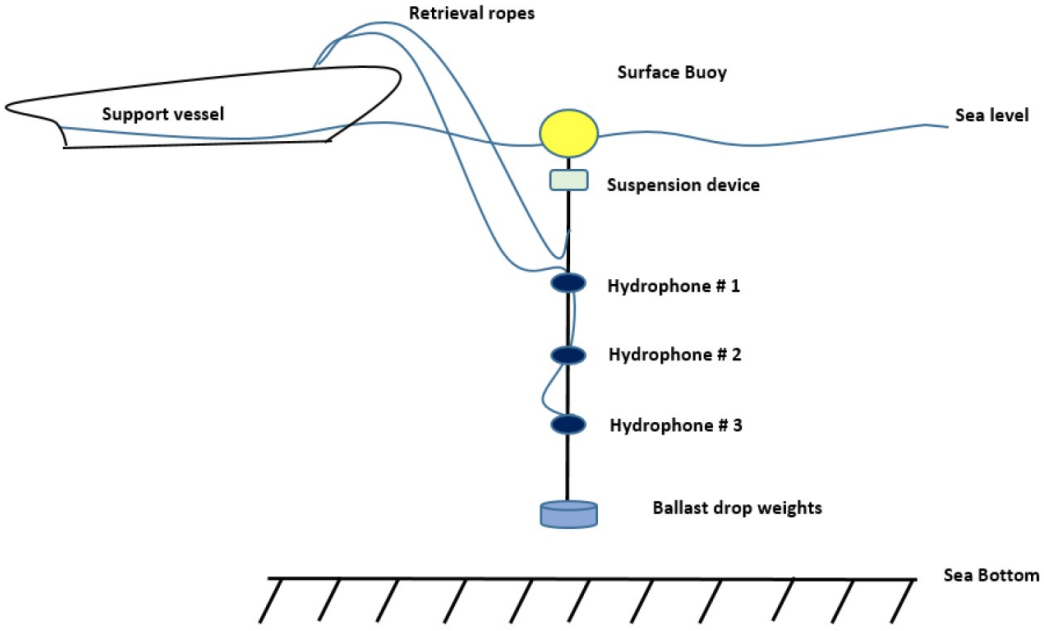
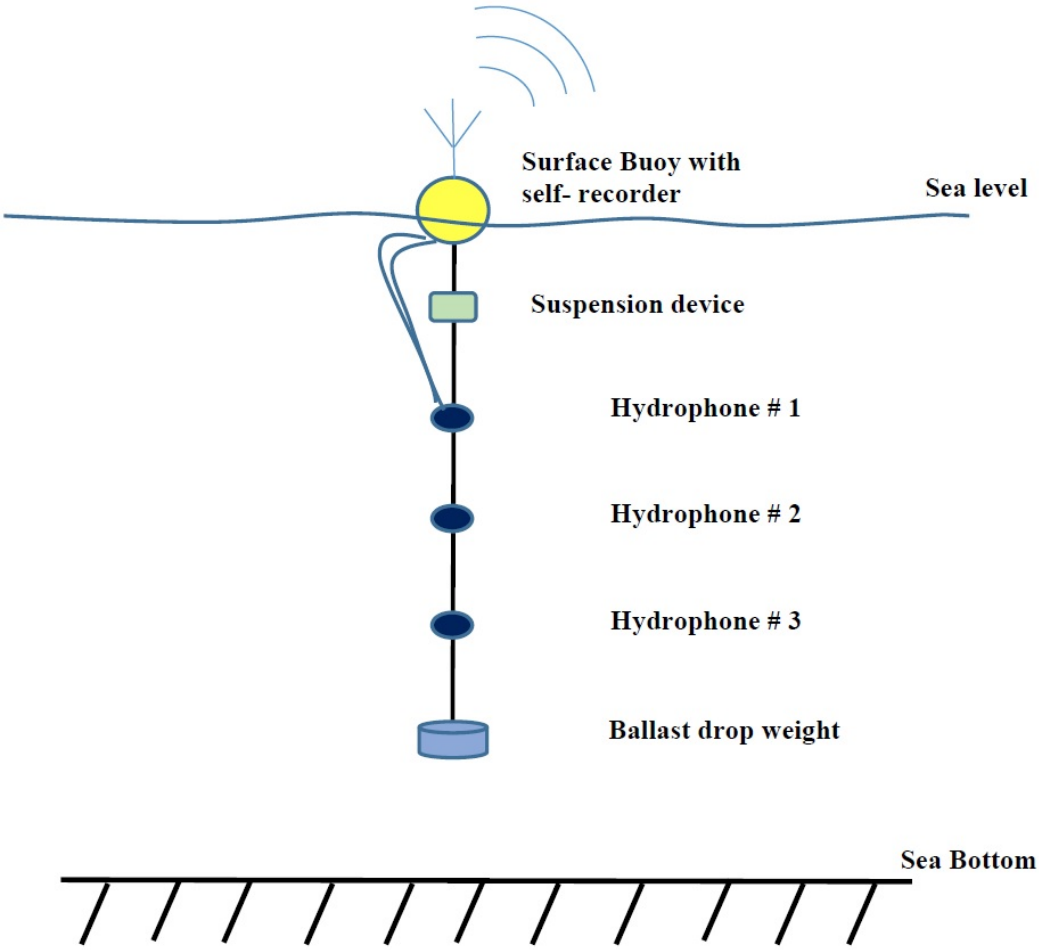


FIGURE 2
Deployment Using a Surface Buoy with an Independent Recorder

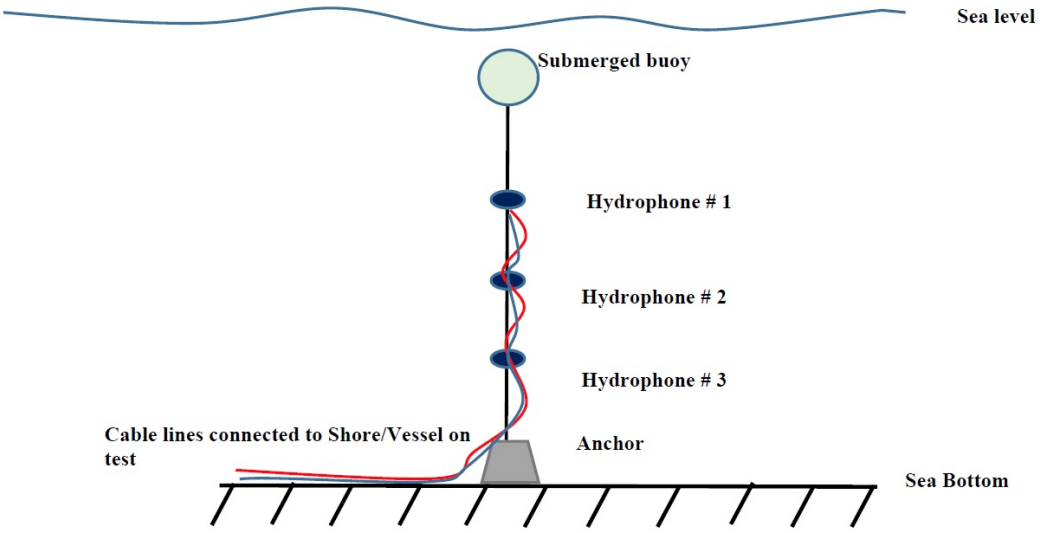


The use of the surface buoy with a recorder allows data to be stored locally. The independent, self-recording receiver platform is contained in the surface buoy, and the radio link allows ease of access to store data.

Radar reflectors are often fitted to the buoys to help avoid damage by possible collisions and help reduce any hazards to ships.

3.3.2 Bottom-mounted System

FIGURE 3
Deployment using Bottom Mounted System (Anchor with Sub Surface Buoy)



3.5 Hydrophone(s) Array Deployment Geometry *(1 May 2021)*

For the measurement to be conducted in shallow water (see 5/9.1), three hydrophones are to be placed vertically down in the water column. One hydrophone is to be placed up to 5 m (16.4 ft) above the sea bottom, and the other two are to be placed approximately 0.5H and 0.25H, respectively, above the sea bottom, where H is the water depth.

For the measurement to be conducted in deep water (see 5/9.1), three hydrophones are to be placed vertically down in the water column at a depth that results from the 15 degree, 30 degree and 45 degree depression angle between the sea surface and the distance from the acoustic center of the vessel to the hydrophones.

The depth of the hydrophones between the sea surface and its corresponding hydrophone may be determined from the following equation:

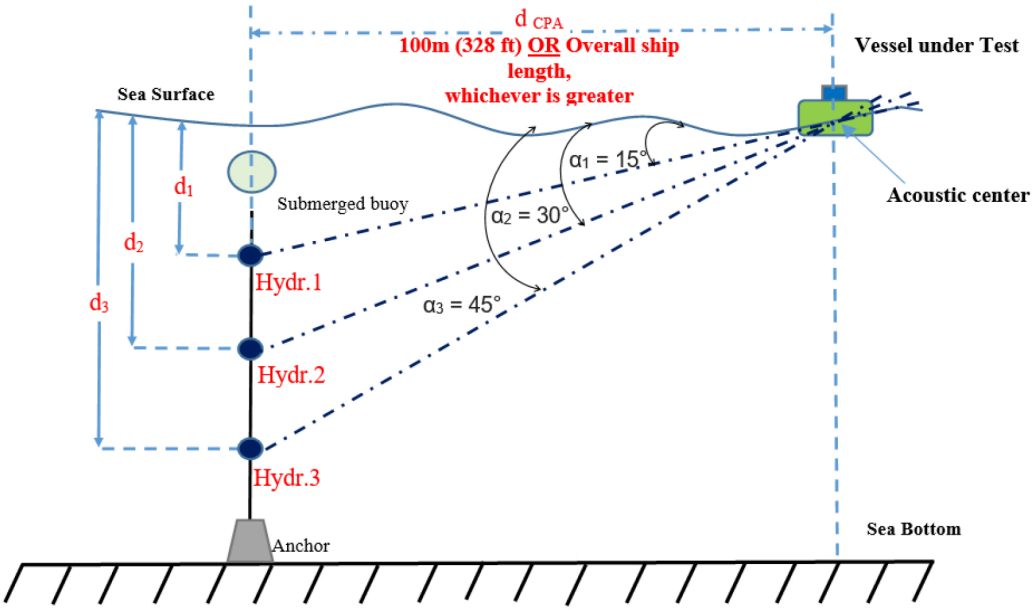
$$d = \tan(\alpha) \times d_{CPA}$$

where

d_{CPA}	=	distance at the CPA, greater of 100 m (328 ft) or overall vessel length (corrected with an accuracy of ±10%)
d	=	depth of the hydrophones (d_1, d_2, d_3) (determined by Pythagorean Theorem), in m (ft)
α	=	15°, 30°, 45° ($\alpha_1, \alpha_2, \alpha_3$)

Other hydrophone deployment methods may be considered provided that the requirements as per Section 4/ Table 1 and the arrangement as shown in Section 4/ Figure 4 are met upon satisfactory review by ABS.

FIGURE 4
Hydrophone Array Deployment with Respect to Vessel under Test *(1 May 2021)*



3.7 Signal Conditioning

The types of electronic devices used for signal conditioning are to be carefully considered so that the data acquisition system effectively and accurately records the mechanical signals produced by the hydrophones. These devices include, but are not limited to, the amplifier, filters, sensor excitation, isolation used with the attenuation, and sampling method input configuration.

5 Data Acquisition and Recording

The sound data acquisition system (DAS), which consists of the DAS hardware, sensors and actuators, signal conditioning hardware, and a computer running the DAS software, is to be capable of acquiring, recording, and converting physical parameters such as the analog signals from the hydrophones to digital representations before being manipulated by the digital equipment.

The DAS is also to be able to obtain the position data of the support vessel or the surface buoy, for instance a global positioning system (GPS) or radar. The position of both the vessel under test and the support vessel or surface buoy (whichever is employed as the means for the deployment of the hydrophones) is to be recorded at the time where the measurement is being carried out. Recording systems are to be synchronized to GPS accuracy before deployment and re-checked after retrieval.

The DAS is to have an appropriate sampling rate of at least 2.5 times of the exact center frequency of the highest frequency band.

As appropriate, all the individual equipment/components in the DAS are to be calibrated to a known output level before and after every major deployment or sea trial.

The information regarding the methods and the instrumentation specification (calibration, accuracy, and sensitivity) that are used for data collection, as well as the means to enable accurate data recording, are to be provided.

7 Sound Data Processing and Display System *(1 May 2021)*

The data processing system (broadband and narrow band) is to be capable of analyzing the sound level to obtain the required data output for the noise assessment as per Subsection 5/15.

The broadband processing of the underwater radiated noise is to cover the one-third octave band frequency range from 10 Hz to 50,000 Hz for commercial vessels and 10 Hz to 100,000 Hz for research vessels. The data processing is to include using the one-third band filters in accordance with Class 1 requirements of IEC 61260.

The narrow band processing is to be in appropriate bandwidths relative to the frequencies. This is usually measured at each 1 Hz frequency. The narrow band processing is to cover a frequency range from 10 Hz to 5000 Hz or higher. Narrow band data can be used for diagnostic purposes as it allows the opportunity to identify specific tones in the noise since the peaks in the measured spectrum can be used to distinguish machinery and systems that are expected to produce identical tones.

Details with regard to the methods, software, and instrumentation used for data analysis of the received acoustic data are to be provided.

SECTION **5**

Underwater Noise Measurement *(1 May 2021)*

1 General *(1 July 2022)*

The underwater noise measurement is to be conducted in accordance with the measurement plan approved by ABS. See Section 2. The underwater noise measurement and the data collection are to be executed by an ABS Service Supplier for Underwater Noise Measurement. The requirements for becoming an ABS Service Supplier for Underwater Noise Measurement can be obtained from the ABS Programs Office or the local ABS office. The test personnel are to complete the Underwater Noise Measurement Data Sheet (see Appendix 1) at the time of the survey.

3 Background Noise Measurement *(1 May 2021)*

Background noise is usually a combination of noise from both environmental and man-made sources.

It is important to determine the background noise level (which is usually present during the measurement at a certain location) so that this can be distinguished and eliminated from the results of the total measured underwater sound pressure level at the end of the test period, allowing for the actual underwater noise measurement to be determined.

5 Distance Measurement *(1 May 2021)*

To measure the underwater radiated noise, it is necessary to acquire the sound pressure measurement at a distance from the sound source and to correct for transmission loss to produce an estimation of the sound pressure level at a reference distance [i.e., 1 m (3.28 ft)].

For the purpose of this Guide, the distance measurement is to be taken between the horizontal distance of the location of the sea surface above the hydrophones and the acoustic center (halfway between the center of the main engine room and the propeller) of the vessel under test, at the CPA.

The accuracy of the distance measurement system is to be within 10% of the distance at the CPA.

7 Other Auxiliary Measurements and Data *(1 May 2021)*

Information that may affect the sound propagation during the measurement test period, and therefore accuracy of the final measurement of the underwater noise levels, is recommended to be recorded.

Taking note of the parameters will provide information on the potential noise contamination with the recording of the underwater noise. This data will also be useful when explaining the deviation (if any) of the final resulting sound signature. Refer to Section 5 of this Guide for more details.

This information includes, but is not limited to, the following:

i) Sea state conditions:

- Seabed composition
- Water column acoustic properties (salinity, water temperature, and density that varies with the water depth to derive the sound speed)
- Tidal deviations in water depth

ii) Weather conditions:

- Rainfall
- Wind direction and speed
- Wave height in relations to the wind speed

iii) Shipping activities near the vicinity:

- Presence of any vessels (their speed, size, and distance from the test site area) operating in the acoustic range/vicinity of the test site
- This could be achieved by means of an Automatic Identification System data
- Presence of any distant noise-generating industrial activity (seismic exploration or offshore construction such as wind farms and hydrocarbon production activities)

iv) Locations of the hydrophones, observation vessel, and recording systems

v) Depth of the hydrophones in the water column

vi) Operating conditions of vessels to be tested (speed, draft, machinery configuration, engine output)

vii) Distance of the vessel under test from the harbor

9 Test Site Requirements

The location of the measurement test site is to be determined by the ship owner, shipyard and approved by ABS before any measurement is carried out. The key factors to consider when selecting a suitable test site are the geographical location and the seasonal weather when carrying out the planned acoustic measurement activity.

Other factors include, but are not limited to, salinity, water temperature, water depth, sea conditions, weather conditions, a safe zone (for the safety and ability of the vessel under test to maneuver taking into account the sea traffic in the vicinity; distance from shore (prevent unwanted reflections), and low background noise (considering the surrounding shipping activities at or near the vicinity of the proposed test site).

9.1 Depth of the Water

For the underwater noise measurement to be conducted in shallow water (water depth less than 150 m (492 ft)), the minimum water depth requirement (from the keel of the vessel under test) is to be 60 m (196.8 ft) or $0.3v^2$m $\left(0.26v^2 \text{ ft}\right)$, where v is the vessel speed in m/s (knots), whichever is greater. The sea floor at the test site is to be as flat as possible.

For the underwater noise measurement to be conducted in deep water and in a far-field condition, the minimum water depth requirement (from the keel of the vessel under test) is to be at least 150 m (492 ft) or 1.5 times of the overall vessel length, whichever is greater.

9.3 Weather/Sea Surface Conditions

Severe/rough weather and sea surface conditions can result in numerous problems such as increasing the background noise and causing the vessel under test or the observation vessel (if used as the means for deployment of hydrophones) to be unstable and thus require the continuous running of the main engine and its propulsion system to maintain its orientation.

The measurements are to be taken under conditions of Sea State 3 or less with a maximum wind speed of Beaufort number 4.

11 Test Conditions of Vessel

11.1 Operation Condition *(1 May 2021)*

The measurements are to be carried out as specified in the proposed measurement plan.

The operation condition of Transit or Research Vessels is to be decided by normal operating condition, or with the main and auxiliary engines to run at least 85% of MCR. For vessels fitted with controllable pitch propellers the measurements are to be carried out in the normal operating condition.

The minimum vessel speed in the measurement for Quiet Operation is to be:

$$v_{quiet,\ \min} = 3.1 + 0.0084\ \ L_{oa} \qquad \text{(SI units)}$$
$$= 6 + 0.005\ \ L_{oa} \qquad \text{(US units)}$$

where

$v_{quiet,\ \min}$ = minimum vessel speed in the test for the Quiet Operation, m/s (knots)

L_{oa} = overall length of the vessel, m (ft)

11.3 Loading Condition

The measurements are to be carried out under a representative loading condition that is reviewed and approved by ABS. The propeller is to be fully submerged.

11.5 Test Course

The vessel is to maintain a straight path on a predetermined course at a constant speed, without excessive rudder actions.

13 Measurement Test Sequence

13.1 General

An example of an underwater noise measurement configuration in a beam aspect test course is shown in Section 5/ Figure 1.

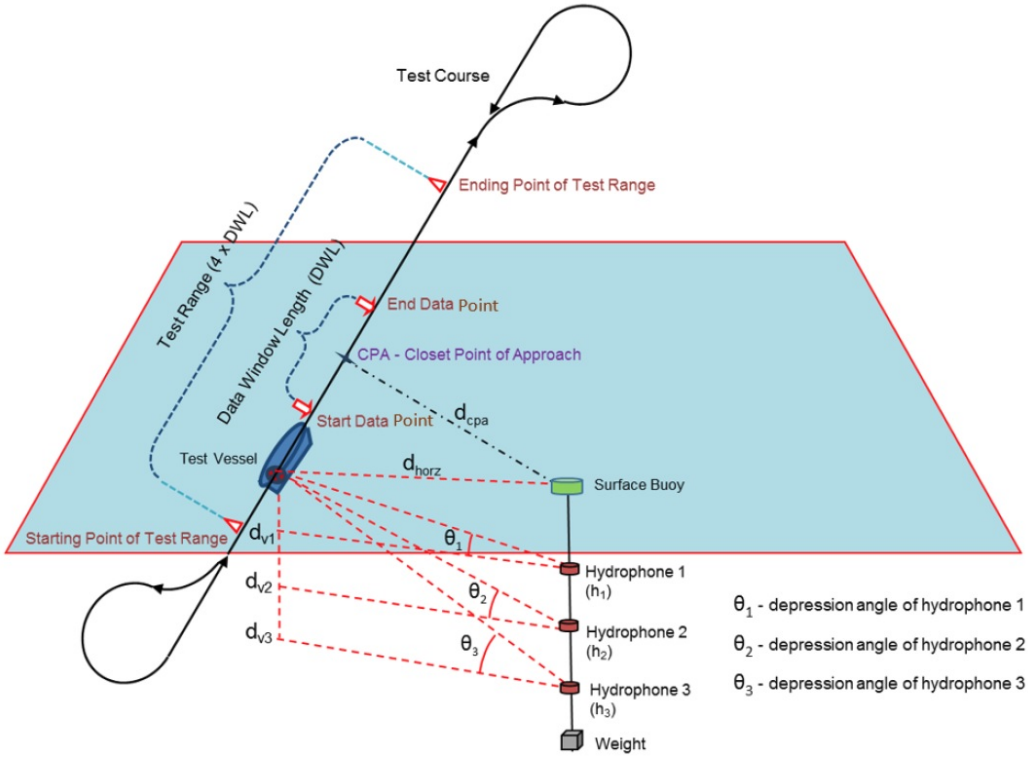
To achieve the required distance at the CPA between the vessel under test and the hydrophones, the vessel is to maintain a straight-line sailing course.

At the Starting Point of Test Range, the required vessel test conditions need to be in place. This includes minimal rudder actions, and maintaining a constant speed and direction, and fixed machinery configurations.

The Starting Point of Test Range is two times the data window length before the distance of the CPA. The Ending Point of Test Range is marked as two times the data window length after the distance of the CPA.

From the beginning to the end of the data recording period, also known as the data Window Length (DWL), the operating conditions of the vessel are to remain unchanged.

FIGURE 1
Underwater Noise Measurement Configuration – Beam Aspect Test Course



13.3 Sea Trial Procedure *(1 May 2021)*

The underwater noise measurements are to be carried out accordingly to the ten steps in a sequential order, as described in 5/13.5.

To reduce the uncertainty due to transmission losses, the test course is to include a total of four (4) repeated runs with alternating runs on each side (port and starboard) of the vessel to be performed for each vessel operational conditions.

The vessel under test typically makes several passes by the array, in order to average port and starboard aspect radiated noise abeam of the vessel. In this Guide, the measurement data are to be collected at each of the three (3) individual hydrophones for four measurement runs being kept separately, two runs at port and two runs at starboard.

These collected data sets are to go through a post-processing phase as described in Subsection 5/15 to account for the unwanted background noise, sensitivity adjustment, and transmission losses.

The radiated underwater noise intensity spectrum obtained from the twelve data sets is the arithmetically average to provide an overall averaged one-third spectrum.

13.5 Underwater Noise Measurement Test Sequence *(1 May 2021)*

i) The main propulsion and auxiliary machinery conditions are to be set up according to the conditions as specified in the measurement plan approved by ABS (Section 2). The same is to be verified by the ABS Surveyor.

ii) The hydrophones and measuring instruments used in the data acquisition system are to be calibrated prior to the underwater noise measurements. The relevant instrumentation reference calibration certificates, together with the results of the field setup and calibration check are to be provided to the ABS Surveyor.

iii) The ABS Service Supplier for Underwater Noise Measurement is to verify that all the measurement systems for carrying out the underwater radiated noise measurement are put in place and are functioning correctly.

iv) At the start and the end of each measurement test run, the background noise measurement is to be carried out and recorded for at least 1 minute with the vessel under test located at the farthest distance or at a distance of at least ≥ 2000 m (approximately 1.08 nautical mile) from the hydrophones, with the same hydrophone deployment and data acquisition methods.

v) During the recording of the background noise measurement, all main engines and generators are to operate only in idle conditions.

vi) After the completion of the background noise measurement, the vessel under test is to proceed to operate at the prescribed operating condition as specified in the approved measurement plan. The operating conditions such as the main and auxiliary engine output, vessel speed, propeller RPM and nominal pitch, and loading condition are to be recorded accordingly.

vii) Before the acoustic center of the vessel reaches the Starting Point of Test Range, the desired operating conditions of the vessel under test are to be achieved. Between the Starting Point of Test Range and the Ending Point of Test Range, the direction and vessel operating conditions are to remain the same.

viii) The data recording of the test measurement for the radiated underwater noise (where the mechanical output signal of the hydrophones is sent to the data acquisition system) is only to commence when the position of the acoustic center of the vessel under test reaches the start data point (beginning of the data window period) and is to terminate when the acoustic center of the vessel under test reaches the end data point (end of the data window period) as shown in Section 5/ Figure 1.

ix) Distance measurements are to be recorded for the vessel under test. These include the distance at the closest point of approach (dCPA), horizontal distance from the acoustic center of the vessel to each hydrophone and the vertical distance between the depth of each hydrophone and the sea surface.

x) The vessel under test is to make a "Williamson Turn" at the Ending Point of Test Range, where the vessel will maneuver and prepare for the next set of runs on the alternate side of the vessel repeating the measurement procedure vi) to ix).

A complete test course requires the vessel under test to perform two (2) repeated runs (with alternating approach) each on the port and starboard side of the vessel under the same operating conditions.

15 Processing and Analysis of Measured Data

The measured underwater radiated sound pressure level from the vessel under test is to undergo a post-processing phase to account for background noise adjustment, sensitivity adjustment and distance correction.

The underwater radiated sound pressure level, which is collected during the data window period (DWP), is to be filtered and applied with the root mean square linear averaged [expressed in terms of dB re 1 μPa (1.45×10^{-10} psi)] in one-third octave bands, as well as in the narrow band spectrum for each run of the measurement.

15.1 Background Noise Correction *(1 April 2024)*

A set of background noise data is to be collected at the beginning and at the end of each measurement run (see 5/13.5). This is to enable the comparison of the sound pressure level radiated from the vessel under test to the background noise level during the period of the measurement test.

The background noise is to be filtered and applied with the root mean square linear averaged (expressed in terms of dB re.1 µPa (1.45×10^{-10} psi) in one-third octave bands as well as in the narrow band spectrum each run of the measurement.

The signal-plus-noise-to-noise ratio, ΔL, for each $^1/_3$ octave band is calculated as shown in Equation 1.

Depending on the output of the signal-plus-noise-to-noise ratio, the following conditions in Section 5/ Table 1 will apply according for the measured underwater sound pressure level of the vessel under test.

TABLE 1
Signal-Plus-Noise-to-Noise Ratio Conditions

Signal-Plus-Noise-to-Noise Ratio	*Conditions*
$\Delta L > 10$ dB	No background noise correction would be required. See Equation 2
3 dB $\leq \Delta L \leq$ 10 dB	Background noise correction is to be applied to the measured underwater sound pressure level. See Equation 3
$\Delta L < 3$ dB	The measured underwater sound pressure level results might be considered as an invalid data ABS would evaluate and consider the validity of the data depending on a case-by-case basis.

Signal-plus-noise-to-noise ratio, ΔL $\quad \Delta L = L_{ps+n} - L_{pn} = 10\log\left(\frac{p_{s+n}^2}{p_n^2}\right)$ (1)

For $\Delta L > 10$ dB $\quad L_p = L_{ps+n}$ (2)

For 3 dB $\leq \Delta L \leq 10$ dB $\quad L'_p = 10\log\left[10^{\left(L_{ps+n}/10\right)} - 10^{\left(L_{pn}/10\right)}\right]$ (3)

where

ΔL = signal-plus-noise-to-noise ratio

p_{s+n} = total underwater sound pressure received at the hydrophones, in µPa (psi). This includes both the underwater radiated sound from the vessel under test and the unwanted background noise.

p_n = sound pressure of the background noise received at the hydrophone, in µPa (psi)

L_{ps+n} = sound pressure level of the vessel under test for each run, in dB

L_{pn} = background sound pressure level taken with the vessel under test being at a distance of 2 km (6560 ft) away from the hydrophones, in dB

L_p = underwater sound pressure level that do not require background noise correction, in dB re 1µPa (1.45×10^{-10} psi)

L'_p = underwater sound pressure level, adjusted to include the background noise correction, in dB re 1µPa (1.45×10^{-10} psi)

15.3 Bottom Effect Correction

If the distance between the hydrophone and the bottom is less than 0.2 m (0.66 ft), a 5 dB reduction to the underwater sound pressure level can be made to correct for the sound reflection from the sea bottom.

15.5 Sensitivity Adjustment

The adjusted underwater sound pressure level L'_p taken into account the background noise correction, is also required to consider the sensitivity aspect of the hydrophone(s) using Equation (4).

$$L''_p = L'_p + H_{SEN} \qquad (4)$$

where

L_p'' = underwater sound pressure level, adjusted to include the hydrophones sensitivity correction, in dB re 1μPa (1.45×10^{-10} psi)

L_p' = underwater sound pressure level, adjusted to include the background noise correction, in dB re 1μPa (1.45×10^{-10} psi)

H_{SEN} = hydrophones sensitivity correction (between 1.5 to 2 dB).

15.7 Distance Correction *(1 May 2021)*

The final underwater sound pressure level, $L_S(r,i)$ is to account for the transmission loss that is to be corrected to a reference distance of 1 m (3.28 ft) for each hydrophone and measurement run using Equation (5).

$$L_S(r,i) = L_p'' + TL \qquad (5)$$

Where

$L_S(r,i)$ = final underwater sound pressure level corrected to a reference distance of 1 m (3.28 ft) based on each run (r) and for each individual hydrophone (i= 1, 2, 3), in dB re 1μPa @ 1 m (1.45×10^{-10} psi @ 3.28 ft)

L_p'' = underwater sound pressure level, adjusted to include the hydrophones sensitivity correction, in dB re 1μPa (1.45×10^{-10} psi)

TL = transmission loss due to the sound propagation through water from the source to the receiver (hydrophones), in dB

For measurement performed in deep water:

$$TL = 20\log\left(\frac{D_{Total}}{D_{ref}}\right) \qquad (6)$$

For measurement performed in shallow water:

$$TL = N\log\left(\frac{D_{Total}}{D_{ref}}\right) + \alpha\left(\frac{D_{Total}}{D_{ref}}\right) \qquad (7)$$

where

D_{Total} = total distance from the acoustic center of the vessel under test to each of the hydrophones, in m (ft)

= $\sqrt{D_{vertical}^2 + D_{horizontal}^2}$

$D_{vertical}$ = depth of the hydrophone from the sea surface, in m (ft)

$D_{horizontal}$ = horizontal distance from the sea surface above the hydrophone(s) to the acoustic center of the vessel under test, in m (ft). This distance could be verified by means of using any distance measurement device (i.e., laser rangefinder, ultrasonic ranging module (sonar, echo-sounding), radar distance measurement, or a GPS system).

$D_{ref}(m)$ = standard reference of distance.

= 1 m (3.28 ft).

N = coefficient of geometric spreading to be determined through acoustic field measurement at the site or detailed analysis. Alternatively, N=18 can be applied.

α = factor for the absorption of sound in sea water. In absence of field measurement or detailed analysis, Section 5/ Table 2 can be applied.

TABLE 2
Factor for Absorption of Sound in Sea Water *(1 May 2021)*

Frequency (f)	α
10 -10k Hz	0
10k – 100k Hz	$2.5 \times 10^{-12} f^2 + 3.6 \times 10^{-8} f$

15.9 Power-averaged of the Sound Source Level from all Hydrophones

$$L_S(r) = 10\log\left[\frac{\left(10^{L_S(r,1)/10}\right) + \left(10^{L_S(r,2)/10}\right) + \left(10^{L_S(r,3)/10}\right)}{3}\right] \qquad (8)$$

where

$L_S(r)$ = power averaged of the sound source level received from the three hydrophones for each test run number, r (r being r_1, r_2, r_3, and r_4), at a reference distance of 1 m (3.28 ft).

$L_S(r,i)$ = underwater sound source level received from the each hydrophone for test run number, r (r being r_1, r_2, r_3, and r_4). See Section 4/ Figure 4.

15.11 Arithmetic Average of the Sound Source Level of the Four Runs under the Same Operation Condition

The results from the test runs data are to be arithmetically averaged using Equation (8) to establish the resulting signature source level for the vessel under a specific operating condition when the measurement runs are carried out.

For different operating conditions, the resulting signature source level value, L_S, is to be determined separately.

$$L_S = \left(\sum_{r=1}^{r=k} L_S(r)\right)/n \qquad (9)$$

where

L_S = resulting signature source level for n number of runs

$L_S(r)$ = power averaged of the sound source level received from the three hydrophones for each test run number, r (r being r_1, r_2, r_3, and r_4), at a reference distance of 1 m (3.28 ft).

n = 4 (total number of runs).

17 Measurement Report *(1 May 2021)*

Upon completion of the underwater noise measurement and measurement data post processing, the measurement report is to be submitted to ABS. The specific contents to be included in the underwater radiated noise measurement report are outlined in 2/5.1.

19 Surveys *(1 July 2022)*

19.1 Initial Survey *(1 July 2022)*

The underwater noise measurement and the data collection are to be executed by an ABS Service Supplier for Underwater Noise Measurement and witnessed by an ABS Surveyor. The requirements for becoming an ABS Service Supplier for Underwater Noise Measurement can be obtained from the ABS Programs Office or the local ABS office.

The test personnel are to complete the Underwater Noise Measurement Data Sheet (Appendix 1) at the time of the survey. Equipment and instrumentation calibration certificates, together with the results of the field setup and calibration check, are to be provided to the ABS Surveyor.

The ABS Surveyor is to verify that the actual underwater noise measurement is carried out according to the approved measurement plan (see Section 2), and sign and file the Underwater Noise Measurement Data Sheet if the measurement meets the applicable requirements.

The main propulsion and auxiliary machinery conditions are to be set up according to the conditions as specified in the measurement plan approved by ABS (Section 2). The same is to be verified by the ABS Surveyor.

The hydrophones and measuring instruments used in the data acquisition system are to be calibrated prior to the underwater noise measurements. The relevant instrumentation reference calibration certificates, together with the results of the field setup and calibration check are to be provided to the ABS Surveyor.

19.3 Surveys After Construction *(1 July 2022)*

See Section 7-9-47 of the ABS *Rules for Survey After Construction (Part 7)*.

SECTION 6

External Airborne Noise Requirements *(1 May 2021)*

1 Requirement for AIRN and AIRN+

The maximum allowable external airborne noise limits at 100 m (328 feet) away from the vessel based on measurements taken in accordance with Section 7 for the **AIRN** and **AIRN+** notations are provided in Section 6/ Table 1.

TABLE 1
Noise Criteria for AIRN and AIRN+ Notation

Notation	*Criteria, L_{Aeq}, in dB re $20\mu Pa$ ($2.9 \times 10^{-9} psi$)*	
	Entire Frequency Range (31.5 – 8000 Hz)	*Low Frequency Range (31.5 -160 Hz)*
AIRN	50	45
AIRN+	45	40

Note: L_{Aeq} is the equivalent continuous A-weighted sound pressure level as defined in Subsection 1/13.

3 Requirement for AIRN-M (a, b)

The notation can be assigned for a vessel where the external airborne noise measurement is carried out in accordance with Section 7.

SECTION 7

External Airborne Noise Measurement *(1 May 2021)*

1 General *(1 July 2022)*

The external airborne noise measurement is to be conducted in port or dockside in accordance with the measurement plan approved by ABS. See Section 2. The external airborne noise measurement can be performed by either individual source measurement or far field measurement method.

The external airborne noise measurement and the data collection are to be executed by an ABS Service Supplier for External Airborne Noise Measurement. The requirements for becoming an ABS Service Supplier for External Airborne Noise Measurement can be obtained from the ABS Programs Office or the local ABS office. The test personnel are to complete the External Airborne Noise Measurement Data Sheet (see Appendix 2) at the time of the survey.

3 Measurement Instruments

3.1 Distance Measurement Device

The accuracy of the distance measurement device is to be 2% of the measured distance.

3.3 Sound Level Meter

Measurement is to be carried out using a sound level meter meeting the requirements of category class 1 of IEC 61672-1. The sound level meter is to have been verified within the last two years by a national standard laboratory or a competent laboratory accredited according to ISO 17025.

3.5 Field Calibrator

The field calibrator used prior to the measurement is to be in compliance with IEC 60942. The calibrator is to have been calibrated within the last two years by a national standard laboratory or a competent laboratory accredited according to ISO 17025.

3.7 Windscreen

A windscreen is to be used to reduce the influence of wind on the reading during the measurement.

5 Test Conditions

5.1 Test Site

Measurements are to be taken under conditions of Sea State 3 or less, as defined by the World Meteorological Organization (WMO) (2014) Sea State Code. Wind velocity is to be below 7 m/s (23 ft/s). Measurements are not to be carried out during rain or snow. Extraneous noise sources are to be avoided. If it is impossible to avoid some extraneous noise sources, they are to be documented and stated in the measurement report.

5.3 Machinery and Equipment Operation

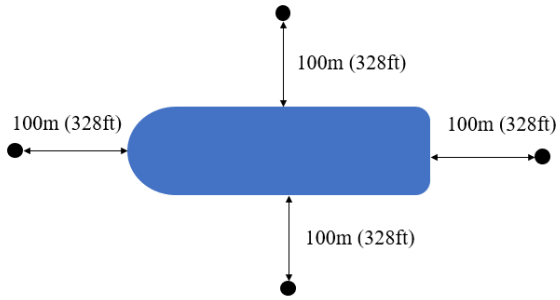
The following machinery and systems are to be switched on during the measurement period: auxiliary engines, engine room ventilations, accommodation ventilations, cargo cranes and cargo ventilation fans (for bulk carrier), reefers (for container ships), pumps on deck (for tankers). Any other equipment that normally operate when vessel berthed in port are also to be switched on during the measurement period.

7 Far Field Measurements

7.1 Measurement Points

One measurement is to be carried out at starboard, port, fore, and aft of the vessel, respectively. Each measurement point is to be at a distance of 100 meters (328 feet) away from the vessel, as shown in Section 7/ Figure 1. The distance is to be measured by a distance measurement device. If the 100 meters (328 feet) distance is not practical, the measurement can be performed at a distance of 80 meters (262.5 feet) to 120 meters (393.7 feet) away from the vessel. In that case, the measurement results are to be corrected to the standardized distance 100 meters (328 feet) by the method specified in 7/7.9.2.

FIGURE 1
Measurement Points for External Airborne Noise Measurements



7.3 Measurement Positions

The microphone is to be at a height of at least 3.5 meters (11.5 feet) above the water surface. If it is mounted on a solid surface, it is to be positioned at least 1.2 meters (3.9 feet) above the solid surface.

7.5 Background Noise Measurement

The background noise is to be measured before and after the external airborne noise measurement for each measurement point. The L_{Aeq} of the background noise is to be at least 3 dB below the L_{Aeq} of each measurement point.

7.7 Data Acquisition

Sound pressure level readings for both external airborne noise and background noise measurement are to be taken in decibels using an A-weighting (dB(A)) filter and also in octave bands between 31.5 and 8,000 Hz. The measurement duration is to at least 30 seconds.

7.9 Post-processing

7.9.1 Background Noise Correction

The L_{Aeq} of each measurement point ($L_{Aeq,i}$) is to be corrected depending on the difference between the L_{Aeq} of background noise ($L_{background}$) and measurement points ($L_{measured,i}$), ΔL_{Aeq}, by the method below:

- If $\Delta L_{Aeq} \geq 10$ dB, no background noise correction is required.
- If $3 \leq \Delta L_{Aeq} < 10$ dB, $L_{Aeq,i} = 10\log\left(10^{L_{measured,i}/10} - 10^{L_{background}/10}\right)$.

7.9.2 Distance Correction

The measurement results are to be corrected if the measurement distance to the measurement position is less or greater than 100 meters (328 feet) using the equation below:

$$L_{Aeq,i}(D) = L_{Aeq,i} + 20\log(D/D_{ref})$$

where

$L_{Aeq,i}(D)$	=	L_{Aeq} of each measurement point corrected to standard measurement distance, in dB(A)
$L_{Aeq,i}$	=	measured L_{Aeq} at each measurement point, in dB(A)
D	=	distance between measurement point to vessel side, in m (ft)
D_{ref}	=	standard measurement distance between measurement point to the vessel
	=	100 m (328 ft)

9 Individual Source Measurements

9.1 Noise Sources to be Measured

The sound power level of all major noise sources of external airborne noise of a vessel are to be measured. Such noise sources are to at least include:

- Funnel outlets of auxiliary engines (not applicable to vessels that only use shore power)
- Ventilation openings of accommodation, hull space, and engine room
- Equipment in operation on open deck, if any (i.e., cargo cranes, oil pumps, etc.)

It may be acceptable to measure one piece of equipment for those of the same model and under the same operating condition, assuming that they emit at the same sound power level.

9.3 Measurement standard

The sound power levels of the individual noise sources are to be measured according to ISO 3746 or ISO 9614-2 or other recognized equipment specific standards for determining sound power levels.

9.5 Post-processing

A numerical model is to be created to calculate the sound pressure level 100 m (328 ft) away from the vessel according to ISO 9613-2. The receiver points are to be at starboard, port, fore, and aft of the vessel as shown in Section 7/ Figure 1. The model is to include the hull, superstructure/deckhouse, all major noise sources, and sea water. The individual noise sources are to be considered as point sources or surface sources. Directivity is to be considered for auxiliary engine funnel outlets.

11 Power Average of Measurement/Analysis Results

The final noise level of the vessel, $L_{Aeq,final}$, is to be an arithmetical average of the measurement with appropriate corrections or calculated noise level of the four receiver points $L'_{Aeq,i}$ in frequency range from 31.5 – 8000 Hz.

$$L_{Aeq,final} = 10\log\left[\frac{\sum_{i=1}^{4} 10^{L'Aeq,i/10}}{4}\right]$$

The final low frequency noise level of the vessel is to be an arithmetical average of the measurement with appropriate corrections or calculated noise level of the four receiver point in frequency range from 31.5 – 160 Hz.

13 Survey *(1 July 2022)*

13.1 Initial Survey *(1 July 2022)*

The external airborne noise measurement and the data collection are to be executed by an ABS Service Supplier for External Airborne Noise Measurement and witnessed by an ABS Surveyor. The requirements for becoming an ABS Service Supplier for External Airborne Noise Measurement can be obtained from the ABS Programs Office or the local ABS office.

The test personnel are to complete the External Airborne Noise Measurement Data Sheet (Appendix 2) at the time of the survey. Equipment and instrumentation calibration certificates, together with the results of the field setup and calibration check, are to be provided to the ABS Surveyor.

The ABS Surveyor is to verify that the actual external airborne noise measurement is carried out according to the approved measurement plan (see Section 2), and sign and file the External Airborne Noise Measurement Data Sheet if the measurement meets the applicable requirements.

13.3 Surveys After Construction *(1 July 2022)*

See Section 7-9-47 of the ABS *Rules for Survey After Construction (Part 7)*.

APPENDIX 1

Underwater Noise Measurements Data Sheet *(1 May 2021)*

Underwater Noise Measurements Data Sheet *(1 May 2021)*

General Information			
Ship's Name		Owner Representative	
Class Number		Yard Representative	
Ship Owner		Test Specialist	
Yard		Person in charge of test	
Class		Surveyor	
Test Schedule		Test Location	

Item	Test Run No.1	Test Run No.2	Test Run No.3	Test Run No.4
Environment Condition				
Sea State				
Wind Speed				
Water Depth				
Weather				
Vessel Traffic				
Vessel Condition				
Loading Condition				
Vessel Speed				
Engine Speed				
Draft				
Other Test Record				
Hydrophone 1 Depth				
Hydrophone 2 Depth				
Hydrophone 3 Depth				
Distance at CPA, d_{CPA}				

	Name	Signature	Date
Ship owner/ Yard:			
ABS:			

	Name	Signature	Date
Test Specialist:			

APPENDIX **2**

External Airborne Noise Measurements Data Sheet *(1 May 2021)*

External Airborne Noise Measurements Data Sheet *(1 May 2021)*

General Information			
Ship's Name		Weather Condition	
Class Number		Sea State	
Ship Owner		Wind Speed	
Yard		Test Specialist	
Class		ABS Surveyor	
Test Schedule			

Measurement Method (Individual source/far field)	
Extraneous noise sources & comments	

Individual Source Measurement			
Noise Source	**Measured Sound Power Level/dB**	**Noise Source**	**Measured Sound Power Level/dB**
E.g. Auxiliary engine funnel outlet			

Far Field Measurement Results				
Location	**Distance to vessel/m**	**L_{Aeq}, dB(A)**	**Background noise, before test, dB(A)**	**Background noise, aft test, dB(A)**
Port				
Starboard				
Fore				
Aft				

Ship owner/ Yard:			
ABS:			
	Name	Signature	Date

Test Specialist:			
	Name	Signature	Date

APPENDIX **3**

References *(1 May 2021)*

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