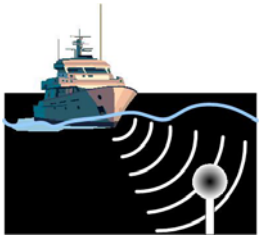

DRAFT ANSI S12.64- 200X
Revision 03, June 5, 2008

WG-47 Committee Draft – Not for Public Distribution
Revision 03, June 5, 2008

AMERICAN NATIONAL STANDARD

Quantities and Procedures for Description and Measurement of Underwater Noise from Ships

Secretariat:

Acoustical Society of America

Draft - Not approved by:

American National Standards Institute, Inc.

Abstract

This standard describes the instrumentation systems, procedures and methodologies for the beam aspect measurement of underwater sound pressure levels from ships. The resulting quantities are nominal source level values. It does not require the use of a specific ocean location, but the requirements for an ocean test site are provided. The underwater sound pressure level measurements are performed in the far-field and then corrected to a reference distance of 1 meter. This standard is applicable to any and all surface vessels either manned or unmanned. This standard is not applicable to submerged vessels or to aircraft. Instrumentation systems are described for measurement of underwater sound pressure levels and also the distance or range between the underwater transducers and subject vessel. Calculations are described to compile data taken from multiple transducers (in some cases), normalize the data to the reference distance. Reporting of the data is described and informational guidance is provided.

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The Acoustical Society of America (ASA) provides the Secretariat for Accredited Standards Committees S1 on Acoustics, S2 on Mechanical Vibration and Shock, S3 on Bioacoustics, and S12 on Noise. These committees have wide representation from the technical community (manufacturers, consumers, trade associations, organizations with a general interest, and government representatives). The standards are published by the Acoustical Society of America as American National Standards after approval by their respective Standards Committees and the American National Standards Institute.

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Contents

Figures

Tables

Deleted: Table 1 – Summary of Measurement Grades . 2¶
Table 2 – Underwater Electroacoustical Transducer Requirements . 6¶

Foreword

[*This Foreword is for information only, and is not a part of the American National Standard ANSI S12.64 - 200X American National Standard Quantities and Procedures for Description and Measurement of Underwater Noise from Ships*].

This standard comprises a part of a group of definitions, standards, and specifications for use in noise. It was developed and approved by Accredited Standards Committee S12 Noise, under its approved operating procedures. Those procedures have been accredited by the American National Standards Institute (ANSI). The Scope of Accredited Standards Committee S12 is as follows:

> *Standards, specifications, and terminology in the field of acoustical noise pertaining to methods of measurement, evaluation, and control, including biological safety, tolerance, and comfort, and physical acoustics as related to environmental and occupational noise.*

This standard is not comparable to any existing ISO Standard.

At the time this Standard was submitted to Accredited Standards Committee S12, Noise for approval, the membership was as follows:

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E.H. Berger	R.D. Hellweg	L.C. Sutherland
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A.J. Campanella	R.J. Peppin	G.E. Winzer
K.M. Eldred	J. Pope	G.S.K. Wong

Working Group S12/WG 47, Underwater Noise Measurement of Ships, which assisted Accredited Standards Committee S12, Noise, in the development of this standard, had the following membership.

Michael Bahtiarian, Chair
Name (if there is a Vice Chair), Vice-Chair

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D. Hazelwood	N. Prater	K. Yankaskas

Suggestions for improvements of this standard will be welcomed. They should be sent to Accredited Standards Committee S2, Mechanical Vibration and Shock, in care of the Standards Secretariat of the Acoustical Society of America, 35 Pinelawn Road, Suite 114E, Melville, New York 11747-3177. Telephone: 631-390-0215; FAX: 631-390-0217; E-mail: asastds@aip.org

Introduction

An Introduction is OPTIONAL. Type the text of your introduction here. Do not duplicate the Scope. Do not include any requirements.

American National Standard

Quantities and Procedures for Description and Measurement of Underwater Noise from Ships

1 Scope

This standard describes the instrumentation systems, procedures and methodologies for the measurement of underwater sound pressure levels from ships. It does not require the use of a specific ocean location, but the requirements for an ocean test site are provided. The resulting quantities are the sound pressure levels normalized to a distance of 1 meter and such quantities shall be considered as "source level" type value. The underwater sound pressure level measurements shall be performed in the far field and then adjusted to the 1 meter normalized distance to be used to compare with appropriate underwater noise criteria. However, this standard invokes no such underwater noise limits.

This standard is applicable to any and all surface vessels either manned or unmanned. The instrumentation and methodology has no inherit limitation on minimum or maximum vessel size. This standard is not applicable to submerged vessels or to aircraft. The methods provided herein have been developed to mitigate Lloyd Mirror (see Section 3) effects, but no specific computational corrections are part of this standard.

The intended use of the standard is a test method to be used to show compliance with contract requirements, periodic assessments and/or research & development. The intended users include: government agencies which own and operate quiet vessels, research vessel operators and commercial vessel owners that need to operate in acoustically sensitive waters.

This standard offers multiple "Grades" of measurement, each with a stated applicability, test methodology, instrumentation accuracy, system repeatability and complexity. A summary of the attributes of each "Grade" (denoted A, B & C) is given in Table 1.

2 Normative references

The following referenced documents are indispensable for the application of this standard. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ANSI S1.1-1994 (R2004), American National Standard Acoustical Terminology.

ANSI S1.6-1984 (R2001) American National Standard Preferred Frequencies, Frequency Levels, and Band Numbers for Acoustical Measurements.

ANSI S1.8-1989 (R2001) American National Standard Reference Quantities for Acoustical Levels.

ANSI S1.11-2004 American National Standard Specification for Octave-Band and Fractional-Octave Band Analog and Digital Filters.

ANSI S1.20-1988 (R 2002) American National Standard Procedures for Calibration of Underwater Electroacoustical Transducers.

Table 1 – Summary of Measurement Grades

GRADE	A	B	C
GRADE NAME	**Precision Method**	**Engineering Method**	**Survey Method**
Measurement Accuracy	± 2 dB	± 3 dB	± 4 dB
Measurement Repeatability	± 1 dB	± 2 dB	± 3 dB
Broadband Frequency Response	10 to 50,000 Hz	10 to 25,000 Hz	20 to 10,000 Hz
Broadband Resolution	~~one-third octave~~	~~one-third octave~~	~~one-third octave~~
Narrowband Frequency Response	10 to 5,000 Hz	As Needed	As Needed
Narrowband Frequency Resolution	1 Hz	As Needed	As Needed
~~System Sensitivity~~	~~<=3 dB below Sea State 0 (Knudsen)~~		
Number of Hydrophones	Three	Three	One
Hydrophone Geometry	Figure 1	Figure 1	Figure 2
Hydrophone Depth(s)	15°, 30°, 45° angle	15°, 30°, 45° angle	~~15~~° Angle
Minimum Water Depth	Greater of ~~200~~ m or ~~2~~x Ship Length	Greater of 150 m or ~~1.5~~x Ship Length	Greater of 50 m or ~~0.5~~x Ship Length
Distance at Closest Point of Approach (CPA)	Greater of 100 m or 1x Ship Length		
Distance Ranging Accuracy (at CPA)	2%	2%	5%
CPA ~~Position~~	Acoustic Center	Ship Center to Propeller	Ship Center
Data Window Angle (± CPA)	±30°	±30°	±30°
Data Window ~~Time, seconds~~	~~Eqn XYZ~~		
Data Window ~~Averaging~~ Time	~~≤~~1 seconds	~~≤~~1 seconds	One Overall Sample
Number of Runs per Condition	~~4~~ Total ~~2~~ Port ~~2~~ Starboard	~~4~~ Total ~~2~~ Port ~~2~~ Starboard	4 Total, At least one Starboard and one Port
~~Deployment Requirements~~	~~No limitations.~~	~~Small craft, such as crew boat. No divers shall be required.~~	~~Small "launch" such as RHIB. No divers required.~~
Weather/Sea Conditions	≤ Sea State 2 (See Section XYZ)		
Auxiliary Measurements	Engine (shaft) speed, Wind Speed & Direction, Sound Velocity Profiles	Engine (shaft) speed, Wind Speed & Direction	Engine (shaft) speed, Wind Speed & Direction
Other Factors	Mitigation of for cable strum and sea surface affects.	Mitigation for cable strum and sea surface affects.	Mitigation for cable strum and sea surface affects
~~Calibration~~	~~Hydrophones field calibrated and Insert Voltage (i.e. full system calibration) Annual Lab Calibration~~	~~Hydrophones field calibrated and Insert Voltage (i.e. full system calibration) Annual Lab Calibration~~	~~Hydrophones field calibrated~~
Laboratory Calibration	Yes	Yes	Yes

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Insert Voltage Calibration	Required over full frequency range	Single frequency & optional to Field Calibration.	Single frequency & optional to Field Calibration.
Field Calibration	Optional	Single Frequency & optional to Insert Voltage Calibration	Single Frequency & optional to Insert Voltage Calibration

3 Terms and definitions (changes not shown to avoid mess)

For the purposes of this standard, the terms and definitions given in ANSI S1.1 and the following apply:

3.1 Acoustic Center. Need definition…Define relative to propeller depth???

3.3 Beam Aspect. Need definition…

3.5 Broadband Frequency Response. Need definition…

3.6 Broadband Frequency Resolution. Need definition…

3.7 Closest Point of Approach (CPA). Need definition…

3.XX COMEX. Need definition…

3.8 CPA Reference. Need definition…

3.9 Data Window Angle. Need definition…

3.10 Data Window Period. Need definition…

3.11 Data Window Sampling Time. Need definition…

3.12 Distance Ranging Accuracy. Need definition…

3.13 End Data Location. The position of the vessel under test 30 seconds after the Start Data Location. See Figure 3.

3.14 End Test Range Location. The position of the vessel under test two times (2x) the "Start Data" distance past the CPA point. See Figure 3.

3.XX FINEX. Need definition…

3.XX Field Calibration. Need definition…

3.15 Grade A Measurement. This grade shall be known as the Precision Method. The Grade A Measurement as denoted in the standard shall have the performance and accuracy as summarized in Table 1-1 and other attributes as given in the rest of this standard.

3.16 Grade B Measurement. This grade shall be known as the Engineering Method. The Grade B Measurement as denoted in the standard shall have the performance and accuracy as summarized in Table 1-1 and other attributes as given in the rest of this standard.

3.17 Grade C Measurement. This grade shall be known as the Survey Method. The Grade C Measurement as denoted in the standard shall have the performance and accuracy as summarized in Table 1-1 and other attributes as given in the rest of this standard.

3.18 Hanning Window. Need definition…

3.XX Insert Voltage Calibration. Need definition…

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Deleted: 3.4 Bow Aspect. Need definition…¶

3.18 Lloyd Mirror Effects. Need definition

3.19 Measurement Accuracy. Need definition…

3.20 Measurement Repeatability. Need definition…

3.XX Measurement System. Need definition…

3.21 Narrowband Frequency Response. Need definition…

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3.22 Narrowband Frequency Resolution. Need definition…

3.XX Omin-directional hydrophone. Need definition…

3.XX Slant Range. Need definition…

3.23 System Sensitivity. Need definition…

3.24 Range. Need definition…

3.25 Overall Ship Length. Need definition…

3.26 Reference Distance. The reference distance for normalizing underwater sound pressure levels shall be 1 meter.

3.27 Sea State 2. Seas with scattered white caps, wave heights no greater than 1 meter (3 feet) range and wind speed no greater than 5 meter/second (10 knots) which is perceived as a gentle breeze.

3.28 Sound Velocity Profile. Need definition…

3.29 Spherical Spreading. Need definition…

3.30 Start Test Range Location. The position of the vessel under test two times (2x) the "Start Data" distance ahead of the CPA point. See Figure 3.

3.31 Start Data Location. The position of the vessel under test where data recording is started. The distance is determined with Equation (1) and shown in Figure 3.

3.32 Test Site. The open water location where the underwater noise measurements are to be performed.

3.33 Underwater Sound Pressure Level. The underwater sound pressure level (SPL) is 20 times the logarithm of the ratio of the rms source sound pressure divided by one micro-Pascal (1 µ-Pascal).

3.XX Vessel Under Test. The ship for which underwater noise measurements are being measured using methodology of this standard.

3.34 Water Depth. Need definition…

3.35 Williamson Curve. Need definition…

4 Instrumentation

In order to quantify the underwater sound from a marine vessel, three main instrumentation components are required: (1) hydrophone and signal conditioning, (2) data acquisition, recording, processing and display system and (3) distance range finding system. The requirements for each of the three components will depend on which of the three Grades of measurement are desired. Detailed specifications of each of the measurement systems are given below.

4.1 Hydrophone & Signal Conditioning

The terms “hydrophone”, “underwater electro-acoustic transducer” or “underwater microphone” may be used synonymously. From hereon this document will use the term “hydrophone” and when used this term shall include any signal conditioning electronics either within or exterior to the hydrophone. The hydrophone(s) should have sensitivity, bandwidth and dynamic range necessary to measure the ship under test and meet the performance for each intended Grade as noted in Table 1. For all Grades of measurement the hydrophone, should be omni-directional across the required frequency range for the Grade. However, directional hydrophones may be used, as long as the directional characteristics are accounted for in final processing (See section 6). The number of hydrophones used to perform the measurement will depend on the Grade. The hydrophones may or may not have integral cable. However, the performance noted above shall be with the full length cable to be used during the test.

~~For all Grades, the hydrophone(s) must come with a “factory” voltage calibration that applies to the entire useable frequency range. For Grades A & B, the hydrophones must be calibrated to an accredited standard, such as ANSI S1.20 within the previous 12 months. For all Grades, the hydrophones must be capable of being field calibrated. For Grade A, the field calibration must be performed for the entire useful frequency range. For Grade B the field calibration shall be performed for at least one frequency in the useable frequency range. For Grade A an insert voltage calibration which takes into account cable performance must be performed.~~

For Grade A, the hydrophones must be calibrated within the previous 12 months to ANSI S1.20, or ISO-XYZ (equivalent standard to be determined) over the entire required frequency range. Prior to and after the measurement series the full measurement system must be insert voltage calibrated (See section 3) over the entire required frequency range.

For Grades B and C, the hydrophones must be calibrated within the previous 12 months to ANSI S1.20, or ISO-XYZ (equivalent standard to be determined) over the entire required frequency range. Prior to and after the measurement series the full data acquisition system must be insert voltage calibrated (See section 3) or field calibrated at a minimum of one frequency.

4.2 Data Acquisition, Recording, Processing and Display

For all Grades of measurement, the data acquisition, recording, processing and display system must be capable of accurately acquiring, recording, processing and displaying data from the hydrophone(s). Such systems may be tape recorders, computer based data acquisition systems or hardware specific devices (such as spectrum analyzers) or combinations of such. The data acquisition system should have an appropriate sampling rate following Nyquist requirements and appropriate dynamic range for either analog or digital systems. For all Grades of measurement a Hanning Window must be applied to the data with an overlap of at least 50%. All frequency-domain averaging must be linear or equivalent exponential with time period consistent with section 5 (Need to think about equivalence (GH & DK).

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For Grades A & B, the time domain signal from each hydrophone, must be acquired and recorded simultaneously (sample accurate) for all three channels. Tracking and time stamp data (See section 4.3) must be recorded synchronously with the acoustic data to enable reconstruction of the track and data processing.

For Grade A measurements, the broadband processing must cover the one-third octave bands from 10 to 50,000 Hertz. Narrowband processing must be in appropriate bandwidths relative to the frequencies to be determined up to 5,000 Hertz, higher as needed. For Grade B measurements, the broadband processing must cover the one-third octave bands from 10 to 25,000 Hertz. Narrowband measurements should be performed only as needed using appropriated bandwidth and frequency ranges. For Grade C measurements the broadband processing must cover the one-third octave bands from 20 to 10,000 Hertz. Narrowband measurements should be performed only as needed using appropriate bandwidth and frequency ranges.

For all Grades of measurement, live audio output and spectrum display of the data are recommended.

4.3 Distance Range Finding System

The distance range finding instrumentation may be any method (optical, acoustical, GPS, radar) as long as the following accuracy is provided. For Grades A & B, the distance range finding system must be accurate to 2% of the distance at CPA. For Grade C, the distance range finding system must be accurate to 5% of the distance at CPA.

For all Grades of measurement for surface suspended hydrophones, the distance range finding instrumentation must only determine the horizontal distance from the sea surface position above the hydrophone(s) to the vessel under test. The slant range from the vessel under test to the hydrophone may be computed during post-processing of the data as noted in Section 6. It is not necessary to take into account any drift which the hydrophones may experience after they are deployed as long as the hydrophone cable drift angle (angle between drifting cable and vertical axis) does not exceed 5°. If the drift angle exceeds 5° then it must either be reduced or the drift angle must be taken into account when determining the slant range as given in Section 6.

For all Grades of measurement for bottom supported hydrophones, the distance range finding instrumentation must only determine the horizontal distance from the sea surface position above the hydrophone(s) to the vessel under test. The slant range from the vessel under test to the hydrophone may be computed during post-processing of the data as noted in Section 6. It is not necessary to take into account any drift which the hydrophones may experience after they are deployed as long as the hydrophone cable drift angle (angle between drifting cable and vertical axis) does not exceed 5°. If the drift angle exceeds 5° then it must either be reduced or the drift angle must be taken into account when determining the slant range as given in Section 6.

For Grades A & B, sufficient data must be recorded in order to determine the vessel track, horizontal range, and speed for the entire measurement run (start to end). This data must be recorded with the data window sampling rate. For Grade C, only the distance at CPA shall be recorded which can be by manual methods.

~~Table 2 – Hydrophone Requirements~~

~~GRADE~~	~~A~~	~~B~~	~~C~~
~~Number of Hydrophones~~	~~Three~~	~~Three~~	~~One~~
~~Frequency Response (one-third octave)~~	~~10 to 50,000 Hz~~	~~10 to 25,000 Hz~~	~~20 to 10,000 Hz~~
~~Voltage Sensitivity~~	~~Section 4.1~~	~~Section 4.1~~	~~Section 4.1~~
~~Horizontal Directivity (DK provide)~~	~~??~~	~~??~~	~~??~~

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For all Grades of measurement, the data acquisition system should have an appropriate sampling time following Nyquist requirements and appropriate amplitude resolution for either analog or digital systems. For Grades A & B time domain data must be recorded.

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~~Vertical Directivity (DK provide)~~	~~??~~	~~??~~	~~??~~
~~Initial Factory Calibration~~	~~Yes~~	~~Yes~~	~~Yes~~
~~Recurring Calibration~~	~~Yes~~	~~Yes~~	~~No~~
~~Field Calibration~~	~~Yes~~	~~Yes~~	~~Yes~~
~~Insert Voltage Calibration~~	~~Yes~~	~~No~~	~~No~~

Table to be deleted paragraph omni-directional to be added to Terms Section.

5 Measurement Requirements & Procedure

In order to perform an accurate measurement of a ship's underwater noise many factors must be correctly addressed. First, an appropriate open water test site must be selected. Second, the hydrophones must be deployed properly. Third, the vessel under test must be operated properly. A complete discussion of all factors is given below.

5.1 Test Site Requirements

This standard does not require the use of a specific ocean location for the measurement "Test Site". It is up to the user to determine the suitability of the proposed test site for the intended measurements. There is a specific requirement for water depth. Some of the other factors to consider are ambient noise, vessel traffic, oceanography, bottom type, local weather, vessel maneuverability and safety.

For all Grades, the background ambient noise should be sufficiently low to measure the radiated noise of the vessel over the frequency range of interest for the Grade. Where the ambient noise limits the measurements, corrections shall be applied (See Section 6).

The water depth at the Test Site will depend on the measurement Grade and is related to the ship length. For Grade A measurements, the minimum water depth shall be 200 meters or two times (2x) the overall ship length whichever is greater. For Grade B measurements, the minimum water depth shall be 150 meters or one and a half times (1.5x) the overall ship length. For Grade C measurements, the minimum water depth shall be 50 meters or one-half times (0.5x) the overall ship length whichever is greater.

5.2 Hydrophone Deployment

For all Grades, the hydrophone is to be arranged vertically in the water column. The hydrophone shall be located to measure Beam Aspect of the vessel under test. For all Grades, the hydrophone shall not be located on the sea bed.

For Grades A & B, the hydrophones shall be positioned vertically in the water column at depths which result from nominal 15°, 30° and 45° angle from the sea surface at a distance equal to CPA (Figure 1). For Grade C, the hydrophone shall be positioned vertically in the water column at a depth that results from a nominal 15° angle from the sea surface at a distance equal to CPA (Figure 2).

5.3 Test Course & Vessel Operation

For all grades, the run configuration is shown in Figure 3. The vessel under test shall transit a straight line course to achieve the required CPA. The starting point of the run (or COMEX) is twice the Data Window Length (DWL) before the CPA. The ending point of the run (or FINEX) is twice the DWL after CPA. At COMEX, the vessel under test shall have achieved the required run conditions. Unless

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For all Grades, the Test Site must be free from continuous vessel traffic. The Test Site should be a minimum of 10 kilometers (≈ 5 nautical miles) from active shipping traffic lanes or areas heavily used for recreational boating. The site should be at least 1 kilometer from shore and have enough room to operate the vessel under test through the test course discussed below (see Section 5.3).¶

Deleted: the ambient noise shall be at least 10 dB below the required underwater sound pressure level limit (if any). If no underwater sound pressure level limit is applicable, then the background noise should be 10 dB below the anticipated sound pressure level of the vessel under test. In all cases, the background sound should not be greater than 150 dB re 1 μ-Pascal in all 1/3 octave bands.¶

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Deleted: Performance of the measurement system is highly dependent on hydrophone ... [4]

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Deleted: centerline of the vessel under test at a distance of nominally one overall ship length.

Deleted: is a diagram of the general configuration.

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required by the run plan, the vessel under test shall maintain constant speed, fixed machinery conditions and minimum use of helm to maintain course through FINEX.

Deleted: The vessel under test shall be complete and fully operational ship. All propulsion systems, auxiliary systems (i.e. HVAC) and navigation systems (radar, GPS, communication) must be fully operational. For newly constructed ships, it is recommended that before any underwater noise measurements are performed, the ship under test has been fully inspected and sea-trialed. For existing ships, it is recommended that the ship be tested after any planned major overhauls or dry-docking. It is also recommended that propellers be cleaned before the underwater noise survey.¶
The ship under test must be able to perform multiple runs though an imaginary test course shown in Figure 3. The course shall be oriented perpendicular to wind and current at the time of each run. The operating conditions of the ship as the noise measurements are performed are entirely up to the user. General guidance on the development of a ship operating test plan is given in Annex A.¶

5.4 Test Sequence

When all aspects of the underwater noise survey are in place the following steps should be used to conduct each test run. For Grades A & B, four (4) runs for each side of the ship (port & starboard) shall be performed for each condition to be tested. For Grade C, four (4) runs for either aspect (port or starboard) shall be performed for each condition to be tested.

a) The vessel captain, master or owner representative shall confirm that the necessary propulsion machinery line-up and auxiliary machinery conditions are set as required.

b) Acoustic test personnel operating the measurement instrumentation shall confirm all measurement systems operational.

c) The vessel under test shall move to a position at least 2 kilometers from the hydrophones and come to full stop. All vessel systems including diesel generators shall remain operating. When in position, the vessel under test shall notify the acoustic test personnel at which time background noise measurements shall be performed.

d) When background noise measurements are completed, acoustic test personnel shall notify the vessel under test to proceed toward the hydrophones at the required vessel operating conditions and speed.

e) When the vessel under test reaches the “Start Test Range” location no further changes to vessel speed or bearing (i.e. steering) shall be made until “End Test Range” location is reached. See Figure 3 for diagram of the two locations.

f) The measurement systems shall start data recording when the vessel reaches the “Start Data” location shown on Figure 3. The “Start Data” distance is dependent on the vessel speed and length

g) When the center-line of the vessel under test is at the CPA position, the distance between the hydrophone and the vessel shall be determined and recorded. It is acceptable to record relative distance between the vessel under test and the hydrophones for the entire run and then use the minimum relative distance as the CPA distance.

h) When the Data Window Time period is completed, the acoustic test personnel shall announce that the “End Data” point is reached. The vessel under test shall continue course to “End Test Range” point before making any changes in vessel operation, direction or speed.

i) At the “End Test Range” point, the vessel under test shall perform the “Williamson Curve” maneuver (see section 3) to run back through the test range on the opposite side and repeat steps (e) through (h). Depending on the Grade, this process shall be repeated for the number of runs as given above.

Background sound measurements, steps (c) & (d) shall be taken at the beginning and end of each test period (i.e. day to half day of measurements). If weather conditions significantly change (i.e. wind increase > 10 mph, increase in sea state or precipitation) the survey shall be suspended and background measurements shall be taken to confirm that background noise requirements are still valid.

6 Post Processing

When the testing is completed as given in section 5, post processing will be required to adjust sound pressure levels for signal-to-noise conditions, sensitivity adjustments and to normalize the data for distance differences. This process is the same for Grades A, B & C. The next step will be to combine multiple hydrophones (Grades A & B only) and multiple runs (all Grades). This process is slightly different for each Grade as given below.

For all Grades of measurement, the Data Window Angle shall be ±30° from the CPA as shown in Figure 3. The CPA shall be no less than one ship length and no greater than twice the water depth. The Data Window Length is the distance traveled by the ship under test within the ±30° window. The Data Window Period shall be the time to travel the Data Window Length as a function of ship speed as given in equation (1).

$$DWP = \left\{ \frac{2xLxTan(30)}{V} \right\} \tag{1}$$

Where DWP is the Data Window Period, L is the overall length of the ship under test in meters, V is the ship velocity in meters/second (multiply knots or nautical miles/hour by 0.514 to get speed in meters/second), Tan(30°) is 0.5773.

For Grade A, the Data Window Period shall be divided into independent samples that are less than or equal to 2 seconds each. A minimum of 10 seconds of data must be taken. The CPA shall be referenced from the acoustic center of the ship. The acoustic center shall be determined using…

For Grade B, the Data Window Period shall be divided into independent samples that are less than or equal to 2 seconds each. A minimum of 10 seconds of data must be taken. The CPA shall be referenced from the center of the ship at speeds below cavitation inception and referenced to the ship's propeller for speeds above cavitation inception.

For Grade C, the Data Window Period shall be one overall sample with minimum of 10 seconds. The CPA shall be referenced from the lengthwise center of the ship for all speeds and conditions.

6.1 Signal-to-Noise Adjustments (All Grades)

A background noise data set must be assigned to each measurement run in order to compare the measured level of the vessel under test to the background noise at the approximate time of the test. The signal-to-noise ratio is defined in equation (2).

If the signal-to-noise ratio is greater than 10 dB, then no adjustments are necessary. If the signal-to-noise ratio is between 3 and 10 dB then adjustments to the measurements are required using Equation 3. If the signal-to-noise ratio is less than 3 dB then the data must be discarded.

$$S / N = 10 \log\left(\frac{S}{N}\right) = L_S - L_N \tag{2}$$

Where S/N is the signal-to-noise ratio computed using equation (2) for each one-third octave band. S is the signal amplitude which is $10^{(Ls/10)}$. This value includes both the desired signal and undesired background noise. and N is the background noise amplitude which is equal to $10^{(Ln/10)}$. L_S is the sound pressure level in decibels with vessel under test present for each run and L_N is the sound pressure level with the vessel under test not present (at 2 kilometer location) (i.e. the background noise level) in decibels.

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$$L_{SN} = 10\log\left(10^{(L_S/10)} - 10^{(L_N/10)}\right) \quad (3)$$

Where L_{SN} is the background noise adjusted signal level with the vessel under test computed in one-third octave bands. Equation (3) is only used if the signal-to-noise ratio is between 3 and 10 dB.

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6.2 Sensitivity Adjustments (All Grades)

Additional adjustments to the L_{SN} value given in section 6.1 shall be made for hydrophone sensitivity, hydrophone directivity and hydrophone cable sensitivity. These sensitivity adjustments are intended to improve the relative frequency dependence the measured signals. Sensitivity adjustments shall be made as given in Equation (4).

$$L_{SN}' = L_{SN} + A_{SEN} + A_{DIR} + A_{CABLE} \quad (4)$$

Where, L_{SN}' is the sensitivity adjusted measured sound pressure level (after background adjustment). A_{SEN} is the adjustment for hydrophone sensitivity, A_{DIR} is the adjustment for hydrophone directivity and A_{CABLE} is the adjustment for cable sensitivity. All three sensitivity adjustments can be measured by the user or provided by the hydrophone vendor.

6.3 Distance Normalization (All Grades)

The final adjustment of the measured sound pressure levels L_{SN}' is normalization of the sound pressure level for distance. The typical distance from the moving ship to the measurement transducer is one ship length. However, due to current and seas this distance may vary by ±10 meters which is acceptable as long as the distance from the hydrophones to the center of the ship is known.

Depending on measurement technology used (GPS, Sonar, or Laser), the distance from the ship to the hydrophone may need to be computed using two separate distances: (1) horizontally from the ship to surface buoy and (2) vertically from the surface buoy to each hydrophone. The total distance from the ship to each hydrophone is determined using equation (5) below.

$$D_{Total} = \sqrt{D_{Horz}^2 + D_{Vert}^2(h)} \quad (5)$$

Where D_{Total} is the total distance to be used the distance normalization Equation (6) below. D_{Horz} is the horizontal distance from the ship to the surface buoy supporting the hydrophone(s). This distance would be what is determined by the distance ranging system (i.e. GPS System, Sonar or Laser Range Finder). D_{Vert} is the depth of the each hydrophone which should be determined during deployment for each hydrophone location, (h, where h1 for shallow hydrophone, h2 for middle hydrophone and h3 for deep hydrophone).

The final underwater sound pressure level for each run and each hydrophone is determined by equation (6) as given below.

$$L_{UW}(r,h) = L_{SN}' + 20xLog\{D_{Total} / D_{ref}\} \quad (6)$$

Where $L_{UW}(r,h)$ is the underwater sound pressure level at a reference distance of 1 meter as a function of run number (r) and hydrophone location (h, where h1 for shallow hydrophone, h2 for middle hydrophone and h3 for deep hydrophone). D_{Total} is the total distance from the vessel under test to each hydrophone (meters) and D_{ref} is the reference distance of 1 meter.

6.4 Grade A Specific Post Processing

For Grade A, the resulting data set from measurements performed in section 5 shall be one-third octave band sound pressure levels in decibels relative to 1 micro-Pascal (dB re 1μPascal) from 10 to 50,000 Hertz. Such data sets will exist for three hydrophones and for four measurement runs per aspect (port or starboard). For Grade A port and starboard aspect runs are to be kept separate. These multiple data sets must be adjusted and normalized according to section 6.1 through 6.3 above. This section describes how to combine the twelve data sets for each condition into one set of values in one-third octave bands.

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The first step in final Grade A post-processing is to determine the power average of the sound pressure level from all three hydrophones (h1, h2 & h3) which results in the sound pressure level for each run, $L_{UW}(r)$ given by equation (7).

$$L_{UW}(r) = 20xLog\{(10^{L_{UW}(r,h1)/20} + 10^{L_{UW}(r,h2)/20} + 10^{L_{UW}(r,h3)/20})/3\} \quad (7)$$

Where L_{UW} (r) is the power-averaged underwater sound pressure level at the reference distance of 1 meter for three hydrophones for run number r. L_{UW} (r,h1) is the underwater sound pressure level for the shallow (h1) hydrophone for run number r. L_{UW} (r,h2) is the underwater sound pressure level for the middle (h2) hydrophone for run number r. L_{UW} (r,h3) is the underwater sound pressure level for the deep (h3) hydrophone for run number r.

The fours runs of data are then arithmetically averaged to determine the final sound pressure value for each run as given in equation (8).

$$L_{UW} = \{\sum_{r=1}^{r=4} L_{UW}(r)\}/4\} \quad (8)$$

Where L_{UW} is the average underwater sound pressure level for four runs as computed in equation (8). It should be determined for each ship conditions of each side of the ship (i.e. port aspect and starboard aspect). This is the final set of values as function of one-third octave band for that condition, that is reported, compared to limits or compared to other data sets.

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6.5 Grade B Specific Post Processing

For Grade B, the resulting data set from measurements performed in section 5 shall be one-third octave band sound pressure levels in decibels relative to 1 micro-Pascal (dB re 1μPascal) from 10 to 25,000 Hertz. Such data sets will exist for three hydrophones and for four measurement runs per aspect (port or starboard). For Grade B port and starboard aspect runs are to be kept separate. These multiple data sets must be adjusted and normalized according to section 6.1 through 6.3 above. This section describes how to combine the twelve data sets into one set of values in one-third octave bands.

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The Grade B post-processing is exactly the same as the Grade A post-processing, except that the one-third octave band data set is only from 10 to 25,000 Hertz. All computations are the same as given in section 6.4.

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6.6 Grade C Specific Post Processing

The resulting data set from measurements performed in section 5 shall be one-third octave band sound pressure levels in decibels relative to 1 micro-Pascal (dB re 1μPascal) from 100 to 10,000 Hertz. Such data sets will exist for one hydrophone and for four measurement runs (port and starboard). For Grade C port and starboard aspect runs may be averaged together. These multiple data sets must be adjusted and normalized according to section 6.1 through 6.3 above. This section describes how to combine the four data sets into one set of values in one-third octave bands.

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The Grade C post-processing will only require use of equation (8) since only one hydrophone is used for this Grade. Also, Grade C will combine port and starboard runs into one data set. Equation (8) is used to determine the arithmetic average of the four measurements runs (r).

7 Measurement Uncertainty

This section will discuss the uncertainty of the underwater measurements, measurement system, and the expected accuracy of the whole measurement process. This section probably needs to be written last.

8 Basis of Acceptability

This section might be fairly short and simply states how to compare or overlay data with underwater noise criteria and what constitutes acceptable noise levels and what is then considered unacceptable.

9 Reporting/Example

This section will list what information is to be reported. Such items would include the ship name and particulars (length, beam, depth, power plant, etc.), where ship was tested, water depth, instruments used, calibration dates, etc. This section could also give example graphs showing the labeling of axes, etc. This section could also give example graphs, giving plotting conventions and showing the labeling of axes, etc.

10 Application Guidance/General Notes

This section may become Informative Annex which provides some practical information on using the standard and making the measurements.

Figure 1 – Grades A & B Hydrophone Deployment Configuration.

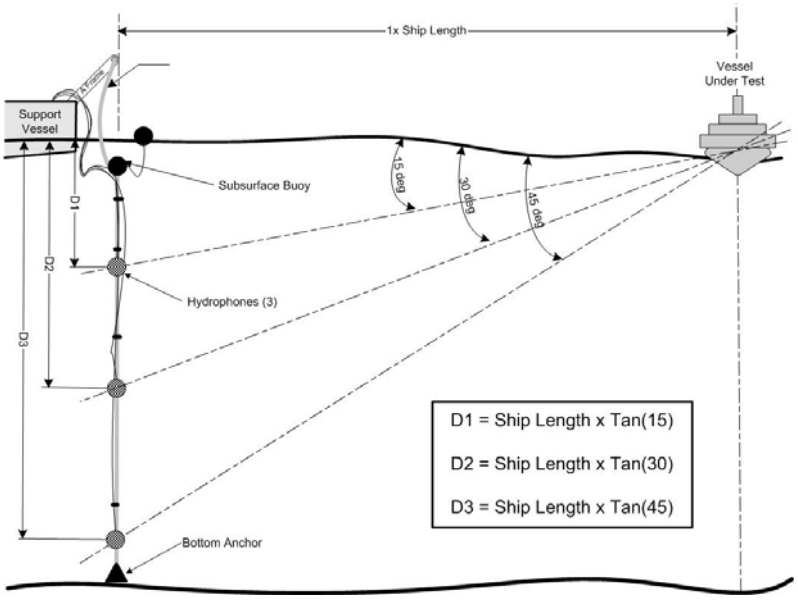


Figure 2 – Grade C Hydrophone Deployment Configuration.

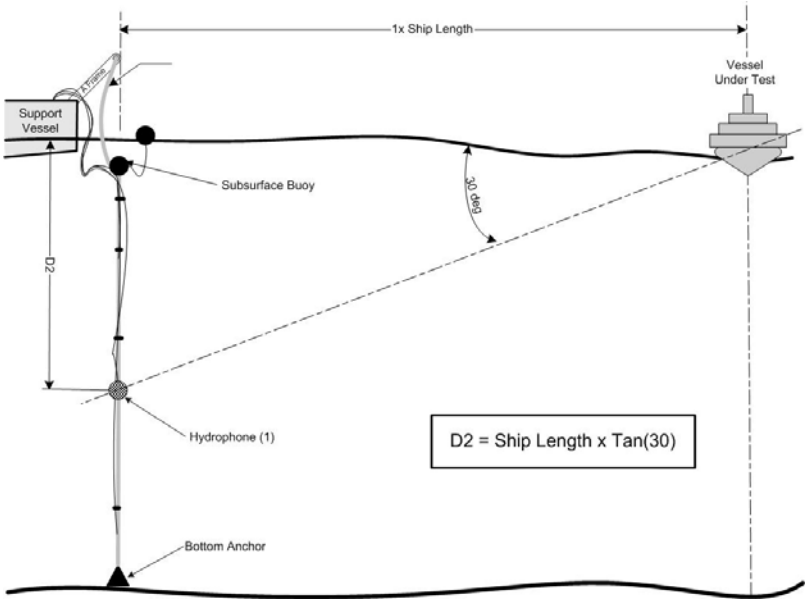
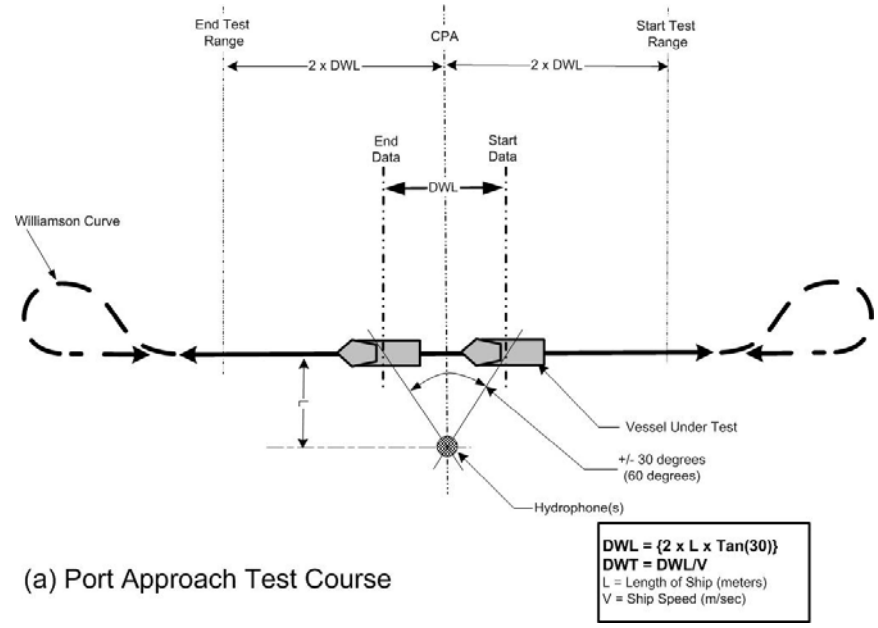
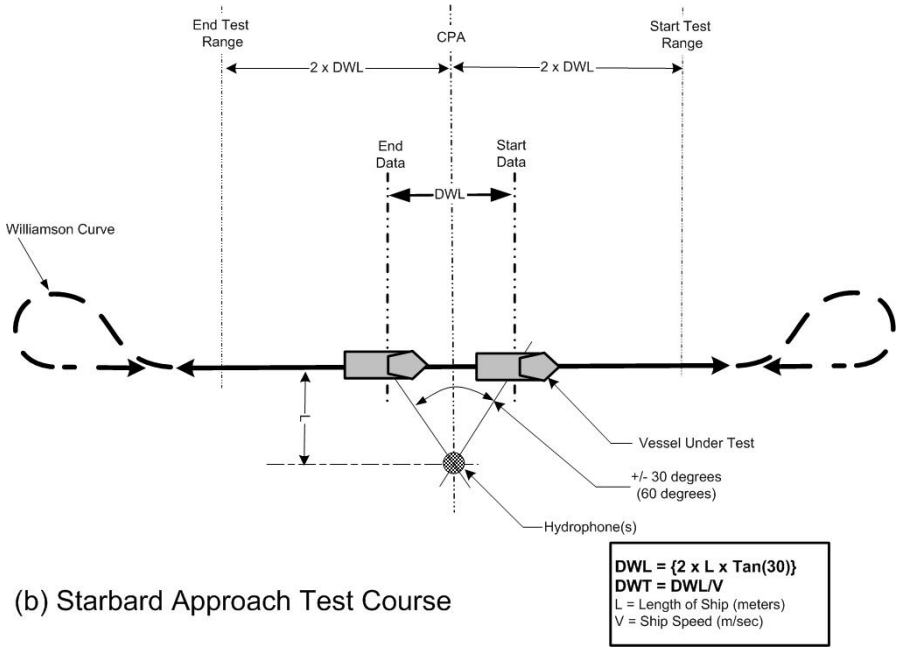


Figure 3 – Test Course Configuration, (a) Port & (b) Starboard approaches.



(a) Port Approach Test Course



(b) Starbard Approach Test Course

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11 Requirements of the standard

11.1 Using styles

To use styles in Microsoft Word, make sure the Formatting Toolbar is active. The styles appear in a drop down menu. To select a style, highlight the text, open the style list, and find the correct style.

11.2 Clause and subclause headings

Choose the Headings from the Styles offered, Heading 1 for Clause headings, 1.1 Heading for subclause headings, and so on. By using the styles offered, the Table of contents will create itself. Headings are available for up to level 6 subclauses, as 4.1.1.1.1.1.1.

11.3 Contents of clauses and subclauses

Most text in clauses and subclauses is formatted using the Normal Style in 10 point type.

11.3.1 Notes and examples

Notes and examples are set in smaller (9 point) type. The format for placing notes in a standard is slightly different if there is one note or example being inserted or two or more.

Example of a single note:

NOTE When a single note is inserted it is not numbered. Using the NOTE Style, type the word NOTE in capitals and strike the TAB key to position the cursor to begin the note.

Example of insertion of two or more notes:

NOTE 1 The word "NOTE" preceded the numeral that is assigned to the NOTE.

NOTE 2 Each note is numbered, with no en-dash or other punctuation separating the number and the text, just a blank space.

Notes and examples should be place at the end of the clause or subclause, or after the paragraph to which they refer.

EXAMPLE Notes and Examples integrated into the text of a standard are preceded by the word NOTE or EXAMPLE in all capital letters.

11.3.1.1 Lists

Insert the text here using the Normal Style. When you want to create a list, choose the list type from the styles offered.

— List continue (for unordered lists)

- List bullet (also for unordered lists)

j) Lettered and numbered lists are available for ordered lists by using one of the List Number styles.

11.3.1.1.1 Subclause

Insert the text here using the Normal Style.

11.4 Equations

Each equation should be numbered in Arabic numerals within parenthesis at the right hand margin.

EXAMPLE The example below demonstrates the placement of an equation number against the right margin.

The amplitude level of the network response is given by,

$$W(f) = 10 \log[K \cdot H*(jf)H(jf)], \quad (1)$$

where K is a normalization constant chosen so that the weighted level is zero decibels at 1000 Hz.

(Indicate if normative or informative)

Insert Annex Title

A.1 Annex clause

A.1.1 Annex subclause

Using Styles A.1, A.1.1, etc., to generate headings for clauses and subclauses within an annex.

Bibliography

Sample Bibliographic entries are given below. Use the Bibliography Style to format the entries. Each entry will be automatically numbered.

There are numerous sources for guidance on bibliographic style and content which vary from one another considerably. The goal is to assure that the bibliography is useful to the reader, enabling the researcher to locate the sources cited.

Bibliographic entries may be arranged either alphabetically by the primary author's surname or in the sequence in which they are cited in the text. The choice should be determined by which method makes the most sense in the particular document.

Standards are not intended to serve as a review of the literature on any topic. Standards shall, however, include complete bibliographic entries for all cited material. Although Bibliographies may include references to source material not cited or to unpublished material, this is discouraged.

In general, each entry shall include as many of these elements as possible: the name(s) of the author(s), title of the book or article, title of journal or magazine if appropriate, edition, volume, publication data (place, publisher, year), page numbers, URL for online documents, and any other relevant data.

EXAMPLE Book with a single author:

[1] Surname, Initials or First name of Author. *Title of Book.* City of Publication: Publisher, year.

EXAMPLE Book with more than one author:

[2] Surname, Initials or First name of Primary Author, First name Surname of Second Author. *Title of Book.* City of Publication: Publisher, year.

EXAMPLE Article in a Journal

[3] Surname, Initials or First name of Primary Author, First name Surname of Second Author. "Title of Article." *Title of Journal,* Volume number, year: pages.

EXAMPLE Online journal or publication

[4] Surname, Initials or First name of Primary Author, First name Surname of Second Author. "Title of Article." *Title of Journal,* Volume number, year: pages. <http://www.online-location.com>

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and heading shall be recorded

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. Such recording may be by manual methods.

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When measurements are being performed, the local weather conditions should be less than or equal to Sea State 2 (see Section 3) without precipitation as a general rule for all Grades. Higher sea states and/or precipitation are allowed as long as the background noise is 10 dB below the intended measurements or underwater noise limit.

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Performance of the measurement system is highly dependent on hydrophone deployment. Deployment methods are more critical in areas of high underwater currents and in higher sea state (i.e. more severe weather).

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For Grade C, the hydrophone shall be positioned vertically in the water column at a depth which results from nominal 30° angle from the centerline of the vessel under test at a distance of nominally one overall ship length. Figure 2 is a diagram of the general configuration.

For all Grades, the hydrophones must be secured to a tether that holds the hydrophone in a fixed vertical position without contact between the hydrophone and the tether. The hydrophone must be pointing upwards. The tether must also minimize horizontal motion from drift which occurs with any underwater current. However, it will not be necessary to factor the drift distance into the distance range computations as long as the drift is less than 5° from vertical. The tether must also be designed to eliminate any cable strum which occurs due to flow induced vibration. This is typically accomplished by adding “anti-strum streamers” to the cable.

For all Grades, the hydrophones must be secured to a tether that isolates vertical motion from surface waves. This can be accomplished with a bottom anchor and subsurface buoy. In such cases, the line holding the hydrophone(s) is anchored to the water bottom and a large buoy holds the line vertically. However, the buoy does not break the surface of the water and typically floats 3-5 meters below the water surface. Hydrophone isolation can also be accomplished by tethering the hydrophones to a surface buoy from a very soft spring (natural frequency < 0.1 Hertz).

Either a ship or surface buoy may be used to support the hydrophones in the water column. In either case, the ship or buoy must not interfere with the noise measurements. For a ship or buoy its anchoring must not create excessive water slap noise or electro-mechanical noise. For a ship, this typically requires shutting down all machinery within the hull and operating on batteries or very small (portable type) generator.