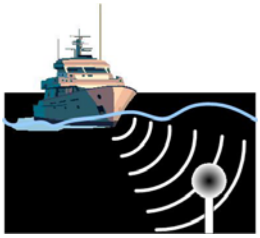

**DRAFT ANSI S12.64- 200X**
**Revision 05, February 5, 2009**

**WG-47 Committee Draft – Not for Public Distribution**
**Revision 05, February 5, 2009**

AMERICAN NATIONAL STANDARD

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

**Part 1 – General Guidelines**

**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) and normalize the data to the reference distance. Reporting of the data is described and informational guidance is provided.

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## 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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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.

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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 for use in comparision 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 the variability caused by Lloyd’s Mirror (see Section 3) effects, but no specific computational adjustments are part of this standard.

The intended use of the standard is a test method to be used to show compliance with contract requirements, enable periodic signature assessments and/or research and 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 Uncertainty | ± 2 dB | ± 3 dB | ± 4 dB |
| Measurement Repeatability | ± 1 dB | ± 2 dB | ± 3 dB |
| Broadband Resolution | One-third octave | One-third octave | One-third octave |
| Broadband Frequency Response | 10 to 50,000 Hz | 20 to 25,000 Hz | 50 to 10,000 Hz |
| Narrowband Measurements | Required | As Needed | As Needed |
| | | | |
| | | | |
| 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 2x Ship Length | Greater of 150 m or 1.5x Ship Length | Greater of 50 m or 0.5x 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 (user selectable) | Ship Center |
| Data Window Angle (± CPA) | ±30° | ±30° | ±30° |
| Data Window Time, seconds<br>Data Window Length, meters | Figure 3 | | |
| Data Window Averaging Time | ≤ 1 seconds | ≤ 2 seconds | One Overall Sample |
| Minimum Number of Runs per Condition | 4 Total<br>2 Port<br>2 Starboard | 4 Total<br>2 Port<br>2 Starboard | 4 Total, At least one Starboard and one Port |
| Recommended Weather/Sea Conditions | None, but must achieve requirements of Section 6.1 | ≤ Sea State 3 | |
| 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 for cable strum and sea surface affects. | Mitigation for cable strum and sea surface affects. | Mitigation for cable strum and sea surface affects. |
| Hydrophone Laboratory Calibration | Yes | Yes | Yes |
| System Insert Voltage Calibration | Required over full frequency range | Single frequency & optional to Field Calibration. | Single frequency & optional to Field Calibration. |
| System Field Calibration | Optional | Single Frequency & optional to Insert Voltage Calibration | Single Frequency & optional to Insert Voltage Calibration |

**Deleted:** Accuracy

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**Deleted:** Narrowband Frequency Response

**Deleted:** 10 to 5,000 Hz

**Deleted:** As Needed

**Deleted:** As Needed

**Deleted:** Narrowband Frequency Resolution

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## 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.** The position on the ship where it is assumed that all of the noise sources are co-located. This position shall be used for all of the spectrum. For this standard, a point one -forth of a shiplength forward of the propeller shall be used, unless a more exact position is known.

**3.3 Beam Aspect**. Need definition…

**3.4 Broadband Frequency Response**. The frequency range for which a system is able to measure, for a given accuracy and repeatability, from a lowest frequency up to the highest stated frequency.

**3.5 Broadband Frequency Resolution**. Sometimes called “bandwidth”, the width of the filters used to effect frequency analysis, stated in terms of either constant bandwidth (“Hz”) or constant percentage bandwidth (sometimes in percent as in “6%” or sometimes as fractional octaves as in “one-third octave band”). In either case, the bandwidth must be stated in universally accepted terms (as in ANSI standard for fractional octave band filters).

**3.6 Closest Point of Approach (CPA)**. Need definition…

**3.7 COMEX**. Short for “Commence Exercise” and is the same as “Start Test Range Location” as described in the definitions and shown in Figure 3.

**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 and definition for FINEX.

**3.15 FINEX**. Short for “Finish Exercise” and is the same as “End Test Range Location” as described in the definitions and shown in Figure 3.

**3.16 Field Calibration**. Not to be confused with laboratory calibration, field calibration is a method of using known inputs, possibly using physical stimuli (such as an known and calibrated/traceable acoustic or vibration source) or electrical input (charge or voltage signal injection) at the input (or other stage) of a measurement system in order to ascertain that the system is, in fact, responding properly (i.e. within the system’s stated uncertainty and accuracy) to the known stimulus. From this, transducer factors (sensitivities) can be adjusted (within acceptable adjustment limits) to compensate for small loss factors in the cables and connections.

**3.17 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.

**3.18 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.

**3.19 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…~~ (NOT REQ'D AS WOULD BE IN NORMATIVE REFS)

**3.20 Insert Voltage Calibration**. A known and calibrated/traceable input stimulus in the form of an electrical input (charge or voltage signal) injected at the input (or other stage) of a measurement system in order to ascertain that the system is, in fact, responding properly (i.e. within the system's stated uncertainty and accuracy) to a known stimulus.

**3.21 Lloyd Mirror Effects.** The alteration of radiated -noise levels caused by the presence of a free (pressure release) surface. Radiation from the "surface image" constructively and destructively influences the source's direct radiation. For this standard, these effects are considered as part of the source's radiation, causing it to exhibit a vertical directivity, necessitating the acquisition angle(s) defined for each Grade.

**3.22 Measurement Accuracy**. The maximum expected/acceptable error ($3\sigma$) stated in ±dB (decibels) for a given measurement system, for one-third octave bands using a given measurement method (averaging time, BT, etc.).

**3.23 Measurement Repeatability**. The maximum expected difference (stated in ±dB), stated in one-third octave bands, between a number of measurements taken at any time given the same inputs and measurement setup/method is used.

**3.24 Measurement System**. A data acquisition system consisting of, but not limited to, a (some) transducer(s), conditioning amplifier(s), analog-to-digital converter(s), digital signal processing computer and ancillary peripherals.

**3.25 Narrowband Frequency Response**. Same as Broadband Frequency Response, but for a spectrum analysis which meets the criteria of Table 1:xxx. Typically an FFT analyzer is used for narrowband analysis, but a constant percentage bandwidth filter analyzer could be used if Table 1:xxx requirements are met.

**3.26 Narrowband Frequency Resolution**. Same as Broadband Frequency Resolution, but for a spectrum analysis which meets the criteria of Table 1:xxx. Typically stated as filter bandwidth less than or equal to some value, usually in "Hz".

**3.27 Omni-directional hydrophone**. An underwater sound pressure transducer that exhibits directional characteristics such that its electrical output responds equally to sound from all directions. The hydrophone is considered omni-directional in the frequency range where, for a given known sound pressure input from any source angle and the same radial distance, the hyrdophone's output response is within a ±2 dB envelope which encompasses the subject frequency range. Sometimes stated separately for axial and radial planes. For example, a given hydrophone may be considered omni-directional for 270° of the axial plane and 360° of the radial plane.

**3.28 Slant Range**. The actual linear distance between the source being measured and the hydrophone, in meters. This takes into account the depth in the water column of the source and hydrophone as well as the radial projection in the plane of the water surface and angle between the CPA ship's course normal to the yyyy line and the ship location at a given measurement aperture point.

**3.29 System Sensitivity**. The response value in mV/unit (sensitivity) for a measurement system which takes into account the hydrophone/transducer sensitivity and the rest of the measurement chain (cables, conditioning amplifiers and filters, and ADC's). Example: mV/Pa. Could also be stated in alternative terms relative to a reference sensitivity such as "-205 dB re 1 V/µPa". *Typically, this would be the transducer sensitivity compensated for cable and conditioning amp influences.*

**3.30 Range**. Need definition…

**3.31 Overall Ship Length**. Need definition…

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

**3.33 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.

**3.33a Sea State 3**. Seas with small waves becoming longer fairly frequent white caps, wave heights no greater than 1½ meters (5 feet) range and wind speed no greater than 8 meter/second (16 knots) which is perceived as a moderate breeze.

**3.34 Sound Velocity Profile**. Need definition…

**3.35 Spherical Spreading**. Need definition…

**3.36 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 and definition for COMEX.

**3.37 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.

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

**3.39 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).

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

**3.41 Water Depth**. 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 measurement 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 the final data 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 cable length to be used during the test.

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 comprise 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).

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 the appropriated bandwidth and frequency ranges necessary to quantify any discrete frequency components. For Grade C measurements the broadband processing must cover the one-third octave bands from 50 to 10,000 Hertz. Narrowband measurements should be performed only as needed using the appropriate bandwidth and frequency ranges necessary to quantify any discrete frequency components.

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

### 4.3 Distance Measurement System

A distance measurement system is required to determine the horizontal separation between the platform acoustic centre and the position on the sea surface above the hydrophone(s) continuously throughout the data acquisition and processing period for Grades A & B and only at the Closest Point of Approach (CPA) for Grade C.

The distance measurement instrumentation may be any method (optical, acoustical, GPS, radar) as long as the following accuracy is provided. For Grades A & B, the distance measurement system must be accurate to 2% of the distance at CPA. For Grade C, the distance measurement 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 that the hydrophones may experience after they are deployed as long as the hydrophone cable drift angle (the angle between the sea surface position and the hydrophone) 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°.

The cable drift angle may be estimated by the use of depth gages that indicate the difference in depth between the hydrophones. If the drift angle is believed to exceed 5°, it must be reduced by attaching weight to the end of the hydrophone cable. Drift angles are usually smaller for surface suspensions that do not utilize a data transmission cable (e.g., an acoustic or electromagnetic data link).

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.

## 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 background noise limits the measurements, corrections shall be applied (See Section 6).

There will be circumstances where the problem of ambient noise limiting the measurable frequencies is insurmountable. In such cases, where measured levels are ambient limited, and no correction is possible (see section 6), then such data must be discarded and no data shown for these frequencies.

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, whichever is greater. 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 the 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° angles 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 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.

## 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 with 2 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, with a minimum of one port and one starboard aspect measurement.

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” (COMEX) location no further changes to vessel speed or bearing (i.e. steering) shall be made until “End Test Range” (FINEX) 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” (FINEX) point before making any changes in vessel operation, direction or speed.

i) At the “End Test Range” (FINEX) 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 noise 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 or traffic conditions significantly change (i.e. wind increase > 15 knots, increase in sea state, ship population or precipitation) the survey shall be suspended and background measurements shall be taken to determine ambient noise levels and confirm that background noise requirements are still valid, and if not, over what frequency range..

## 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).

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

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 or Δ is defined in equation (2).

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

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

Where Δ 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. 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.

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

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.

Since unexpected changes in background noise often occur (e.g., a passing ship or a rain squall) a signature measurement's background must be assessed at the beginning of each event in order to estimate any background noise contributions to the measurement SPL and perform remedial adjustments to the data, if necessary. As the ship closes to the measurement system, a background measurement (30 second average) is made when the ship's distance is at least four times that of the distance prescribed for the acquisition of signature measurement data. During this background measurement, the signature data levels will be more than 12-dB less than their levels at the prescribed signature measurement distance. If the background data are actually dominated by the ship's noise, the signature data will be deemed unaffected. If the data need to be modified, the adjustments are made to one-third octave data. Attempts to adjust discrete frequency data have usually led to undesirable results and are not recommended.

## 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).

$$L_{SN}' = L_{SN} + A_{SEN} + A_{DIR} + A_{CABLE} \tag{4}$$

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.

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

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.

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

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. This normalization assumes that the ship is a directive source at the surface; i.e., the surface image is considered as part or the source.

## 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.

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).

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

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).

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

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.

## 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.

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.

## 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 50 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.

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

Measurement uncertainty is controlled by measurement accuracy and repeatability. Both are discussed below.

Measurement accuracy is affected by a combination of random errors and basis errors. For the sound pressure level (Lp) for each one run, the total random error includes the combined effect of several half-to-one dB errors associated with the acquisition system, typical values being: calibration (0.5 dB); sensitivity (<1 dB); data processing (0.5 dB) and amplifier gains (0.5 dB). These errors have an rms (root mean square) value of about 1.25 dB.

Signature (source level) calculations for each hydrophone have decreased accuracy because of the range adjustment errors. These errors (~1 dB) include errors associated with uncertainty in the horizontal range, assumption about the acoustic center and other system parameters; hydrophone depth, thermal gradient, etc. The rms random error for a source level estimation characterized by errors such as these would be about 2 dB, and the average of three hydrophones would be <1.5 dB (some errors, such as ranging, would be the same for each hydrophone), the value specified for navy acoustic ranges.

When comparing data acquired using different measurement grades, data differences may be expected because of the basis errors associated with each of the types. Proximity of the surface and bottom usually causes biases in the data. The amount of bottom contribution is smallest when the ratio of measurement distance to bottom depth is the smallest. This ratio is about two for Grade C, one half for Grade B and less than one third for type A. Comparisons between the types for the same ship will be affected by these biases as well as other factors such as ship's directionality. For simple bottoms, the biases should be within 1 dB of the values shown below. The values in parenthesis are estimates of the combined effects of surface and bottom below 500 Hz.

TABLE 2: Typical Data Comparison Differences Caused By Boundaries

| **Data comparison** | **Grade A data compared to Grade B** | **Grade A data compared to Grade C** | **Grade B data compared to Grade B data** |
|---|---|---|---|
| **Typical result above (below) 400 Hz** | Grade B data 1(2)-dB greater than Grade A data | Grade C data 2(3or4)-dB greater than Grade A | Grade C data 1(1or2)-dB greater than Grade B |

Repeatability for the measurements addressed by this standard is affected by the ranging random error and signal processing random error, the errors that differ from run to run. The average of two or more runs mitigates the repeatability by the square root of the number of runs. The estimates given above are typical, not exact. The source levels are also affected by the repeatability of the radiation from the ship.

## 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.**

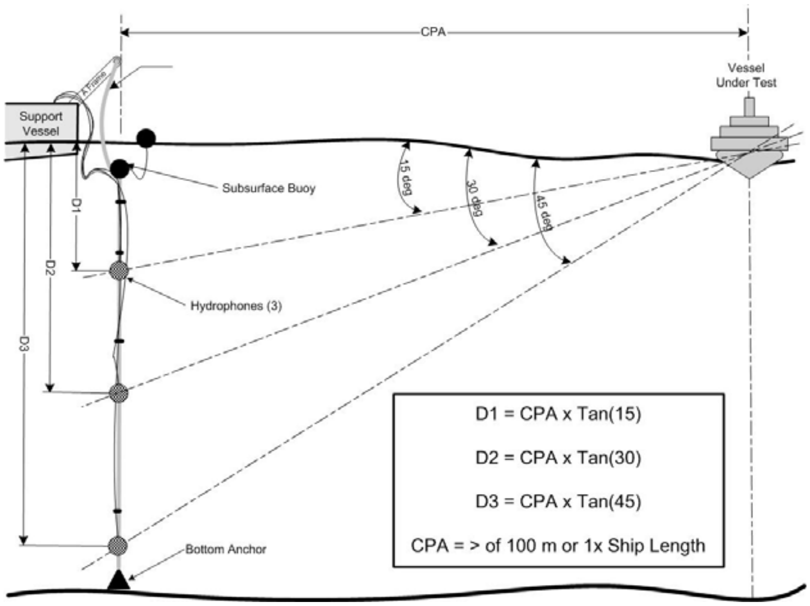



**Figure 2 – Grade C Hydrophone Deployment Configuration.**

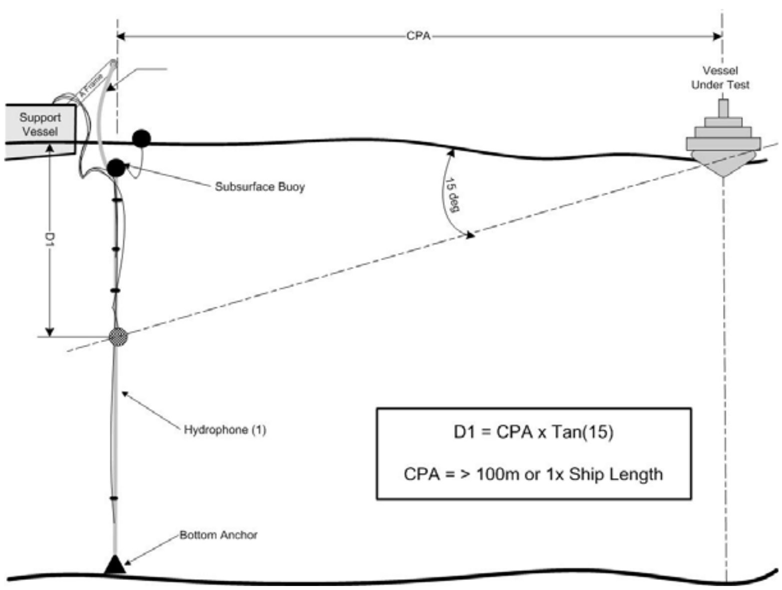
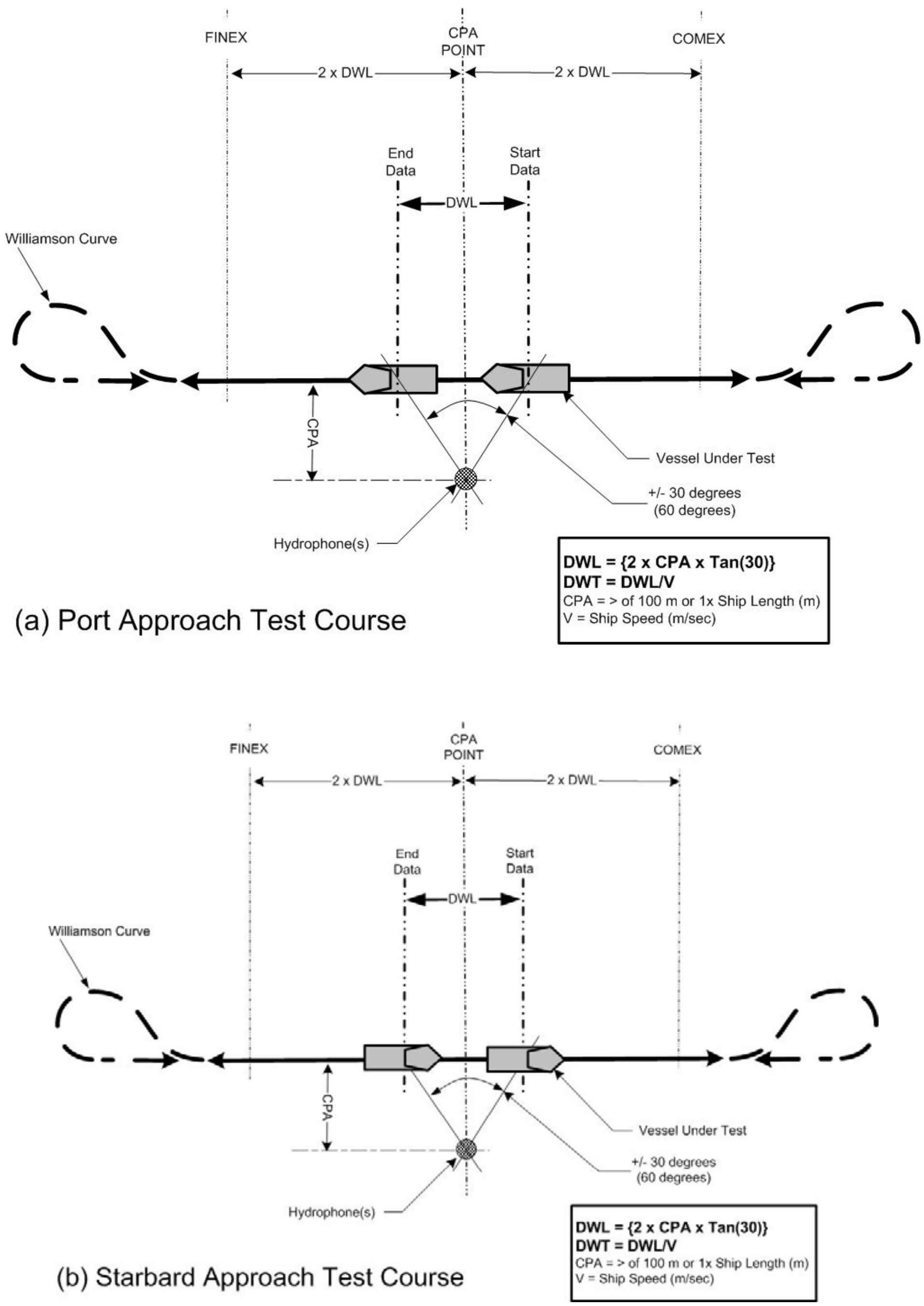


**Figure 3 – Test Course Configuration, (a) Port & (b) Starboard approaches.**



(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>