ASA STANDARD GOES UNDERWATER

Michael A. Bahtiarian
Noise Control Engineering, Inc.
799 Middlesex Turnpike
Billerica, Massachusetts 01821

This fall the Acoustical Society of America (ASA) published a new standard for the measurement of underwater sound from ships. ANSI/ASA S12.64-2009/Part 1, "*American National Standard, Quantities and Procedures for Description and Measurement of Underwater Sound from Ships-Part 1: General Requirements*" as it is now known, has a couple of firsts. It is the first ASA noise standard concerned with underwater sound. More importantly it is the first known civilian standard in the world for quantifying the underwater sound of ships. The need for this standard grows out of environmental concerns and efforts to reduce all types of vessel emissions. Initially, the focus was on the reducing ballast water and engine emissions, but concern about ship noise has been growing over the past decade or more.

"…it is the first known civilian standard in the world for quantifying the underwater sound of ships."

The standard was developed by S12/Working Group 47, a subgroup of ANSI Accredited Standards Committee S12, Noise, which is administered by the ASA. Members of the working group included professionals from government, academia, and industry. Government members included personnel from Naval Sea Systems Command (NAVSEA), Naval Surface Warfare Center (NSWC), and National Oceanic and Atmospheric Administration (NOAA). Academia included members from the University of Delaware, Lamont-Doherty Earth Observatory, Florida Atlantic University, University of Rhode Island, and University of New Hampshire. Industry included private consultants to Fortune500 companies. International participation came from Canada, United Kingdom, the Netherlands, and Australia.

Since World War II, the field of underwater acoustics has been the sole concern of the navies of the world, which have used this special knowledge to hide their submarines while in the hunt for enemy submarines and surface combatants. The non-military interest in underwater sound is attributable mostly to reducing anthropogenic noise or man's impact on marine animals. "Excessive underwater noise has the potential to interfere with a marine animal's ability to perform a variety of critical life functions such as navigate, communicate, find food, etc."[1]

A further necessity of this new standard for measuring ship noise came from the author's involvement in design, construction and testing of quiet research vessels starting around 2001. The U.S. Department of the Interior, National Oceanic and Atmospheric Administration has procured a fleet of ships that perform fish stock assessment (fish counting) using sonar. To conduct such activity, NOAA needed a new Class of quiet fisheries research vessels. The first of the Class is the *OSCAR DYSON* which was put into service around 2004. Since that time, three similar vessels (*HENRY BIGELOW, PIECES* and *BELL SHAMADA*) have been delivered to NOAA. Other quiet vessels include a coastal research vessel for the University of Delaware (*R/V SHARP*), two Regional Class Research Vessels (RCRV), and one Arctic Area Research Vessel (AARV). Both the RCRV and AARV are expected to be funded by the National Science Foundation (NSF). However, RCRV has not yet been funded and AARV is, at time of writing, undergoing shipyard selection.

The contracts for all of these quiet research vessels have underwater noise requirements that either already have been verified or will need to be verified in the future. All existing vessels have had their underwater sound measured at one of four different U.S. Navy facilities (one on the U.S. East Coast, two on the U.S. West Coast and one in Alaska).

It is hoped that the new standard will promote consistency among those reporting sound measurements including non-military government agencies, non-government organizations (NGOs) and the private sector. The standard describes requirements for instrumentation, measurement procedure and post processing. The standard has three different grades denoted A, B, and C. Grade A is the precision method intended for contract requirement conformance testing. Grade B is an engineering method which could be used for less critical contract requirements and/or periodic assessments. Grade C is a survey method which would be used for periodic assessments and "quick-look" tests.

The section on "Instrumentation" covers types of hydrophones, data acquisition systems, distance ranging and calibration. Hydrophones need to be omni-directional and be capable of measuring over the frequency response specified for each grade. Grades A and B require three hydrophones and Grade C requires just one hydrophone. Data acquisition systems need to be able to perform over the specified frequency range, take one-third octave band measurements and, in some cases, narrowband measurements. The standard is primarily based on one-third octave band filtering with frequency ranges that depend on the Grade. Grade A is from the 10 to 50,000 Hz one-third octave bands. Grade B is from the 20 to 25,000 Hz one-third octave bands and Grade C is from the 50 to 10,000 Hz one-third octave bands.

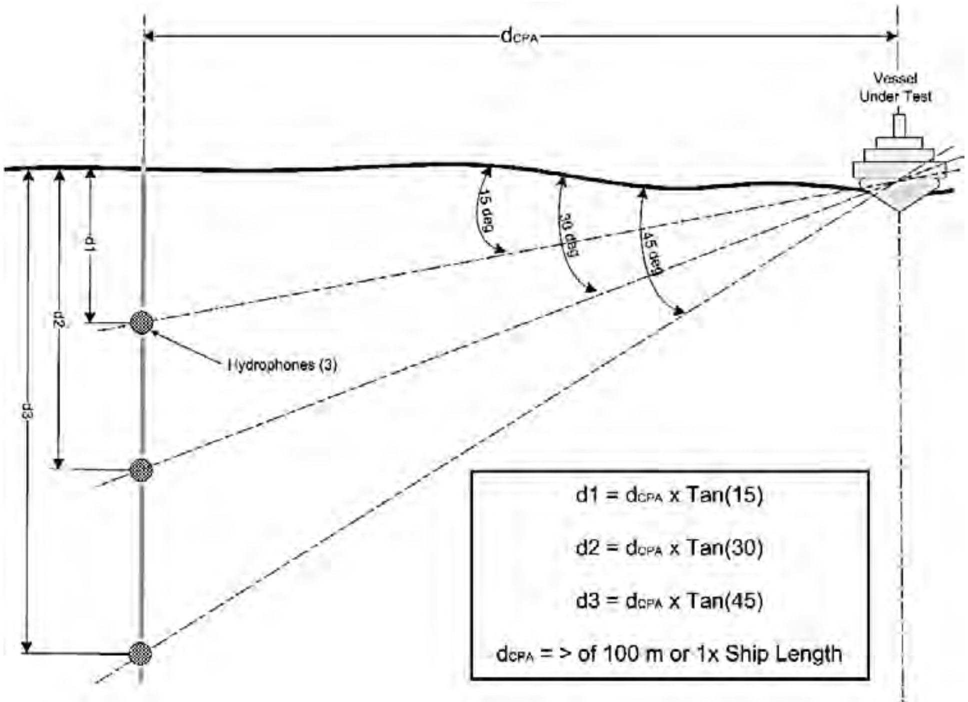

Fig. 1. This diagram is taken from ANSI/ASA S12.64-2009/Part 1 and shows the hydrophone geometry for Grades A and B. D_{CPA} is the distance at the "Closet Point of Approach" that is set equal to the ship's length, but no less than 100 meters. This insures the measurements are being taken in the far-field. The distances d1, d2 & d3 are the hydrophone depths, which are functions of D_{CPA}. Grade C is similar to this figure except the top and bottom hydrophones are deleted. Used with permission from the Acoustical Society of America, © Copyright 2009.

Distance determination (ranging) is necessary to normalize the sound pressure levels to a distance of 1 meter. The final results are "source" sound pressure level (SPL) values normalized from typical measurement distances of 100 meters (or at least one ship's length) to the reference distance of 1 meter. In actuality, the underwater sound pressure levels are affected by other factors besides distance from the ship to the hydrophones. These other factors (that are ignored in this standard) include the presence of the free surface and bottom reflections. The resulting quantities are thus considered "affected source levels," but referred to within S12.64 as just source levels. The resulting data could alternately have been reported in the form of sound power levels (Lw). However, all previous work by the U.S. Navy and many others has used the "SPL at 1 meter" parameter. Early in the standard development, it was decided that the final resultant would use this existing parameter and not create any new acoustic metrics. The section on "Measurement Procedures" includes requirement conditions for a suitable test site, sea state conditions, hydrophone deployment, test course, vessel operations, and the test sequence. Another requirement that was agreed upon early in the standard development was that no special ocean location be specified. For the most part, naval underwater test ranges use very selective locations which have deep water and low background noise.

Since no specific open ocean location or locations are required, the standard has requirements for water depth and background noise. Other factors related to site selection are the proximity to main shipping traffic, bottom type and space available for maneuvering. The standard does not provide hard and fast sea state (or weather) requirements other than recommendation that testing be conducted with wind less than 20 knots (10.28 meters/second). However, the measurement system needs to meet background noise requirements so measurement of a quiet ship in rough seas may not be possible. On the other hand, measurement of a noisy ship might be accomplished.

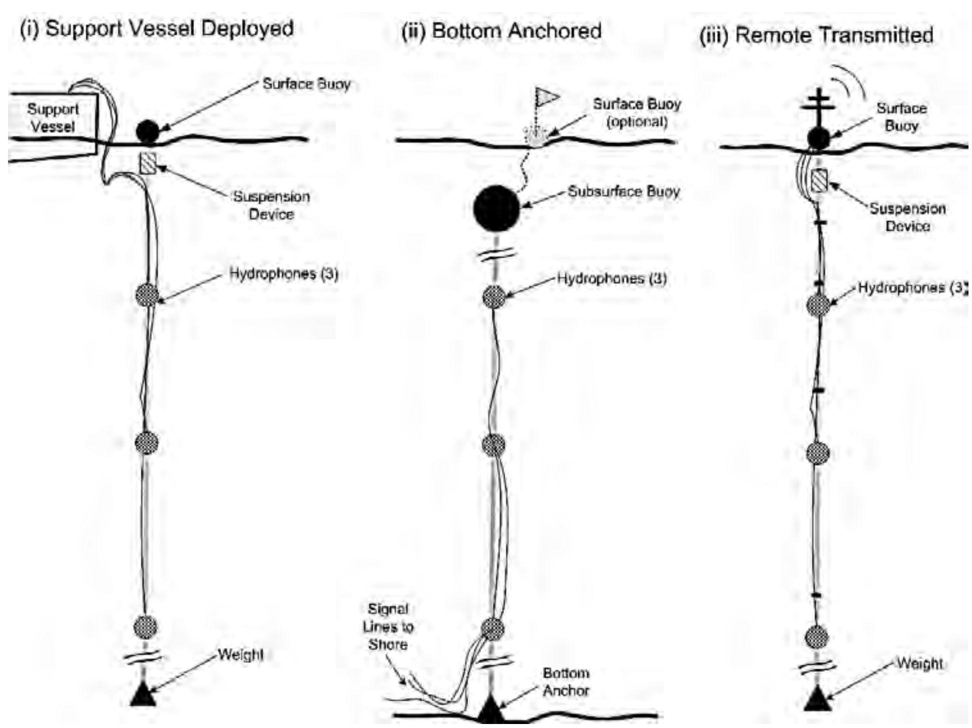

Fig. 2. This diagram is taken from ANSI/ASA S12.64-2009/Part 1 and shows three possible hydrophone deployment configurations that could be used for any Grade. Other configurations or combinations of these three configurations are certainly possible as long as the basic requirements of the standard are achieved. Used with permission from the Acoustical Society of America, © Copyright 2009.

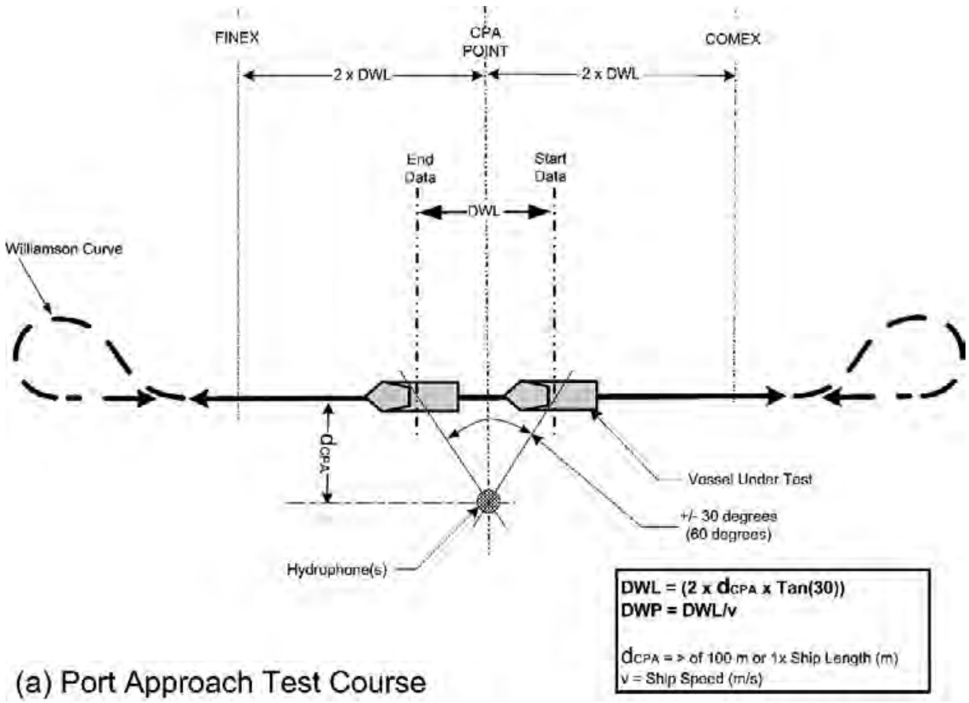

Fig. 3. This diagram is taken from ANSI/ASA S12.64-2009/Part 1 and shows a top down view of the ship's "Test Course" configuration for port approaches to the hydrophone(s). The starboard approach is simply in the opposite direction. The Data Window Length (DWL) and Data Window Period (DWP) are defined by equations in the box in the lower left corner. Both DWL and DWP are bound by the "Start Data" and "End Data" points. U.S. Navy typically uses COMEX and FINEX as points for starting data and ending data collection. For this standard COMEX and FINEX define points where ship operations must be maintained during the test run. Used with permission from the Acoustical Society of America, © Copyright 2009.

Hydrophone deployment must follow a strict set of geometrical constraints that depend on the measurement Grade (A, B or C) and ship length. Figure 1, extracted from ANSI/ASA S12.64-2009/Part 1, shows the configuration for Grades A and B. The configuration for Grade C is similar except the top and bottom hydrophones are eliminated. Figure 2, again extracted from the standard, shows three typical deployment configurations that could be used for each of the Grades.

Figure 2(i), support vessel deployed, is the simplest configuration, but has limited low frequency performance because sea state motion from the surface is transferred to the hydrophones. A very soft suspension system along with other features is required to get useful measurements below 100 Hertz. Figure 2(ii) shows a configuration where the hydrophones are bottom anchored and the cable is kept tight by a sub-surface buoy. This approach is more complicated but greatly aids in low frequency performance. Figure 2(iii) combines elements of the other approaches and adds the use of telemetry. Although more technology is required, this configuration results in better data and has the potential to eliminate the need for a support ship.

Figure 3, also extracted from the standard, is a top down view of the vessel's test course for port approaches. The ship's noise is measured as it approaches the hydrophones which are suspended vertically in the water column. At COMEX (Navy term for "commence exercise") the vessel must maintain a constant speed and course until FINEX ("finish exercise") is achieved. SPL measurements are taken between the COMEX and FINEX points. Most Navy ranges start and end data acquisition at the COMEX and FINEX locations. Grades B and C which may use simpler methods will then take measurements within "Start Data" and "End Data." points. The difference in distance between these two points is called the "Data Window Length" defined in the standard based on the length of the ship. The "Data Window Period" (time) is based on ship length and ship speed.

The section on "Post Processing" includes specification of the Data Window Length/Period, background noise adjustments, sensitivity adjustments, distance normalization and combination of data from multiple hydrophones and multiple runs. The final results are reported in one-third octave bands, sound pressure level in decibels relative to one (1) micro-Pascal normalized to one (1) meter distance. These units are consistent with the U.S. Navy databases collected over the last forty years.

The background sound adjustment uses standard decibel subtraction between SPL with the ship going by the hydrophone less SPL with the ship at least 2 kilometers away. Distance normalization uses standard spherical spreading from the acoustic center of the ship to each hydrophone. This was one of the most discussed elements as underwater sound propagation is much more complex than the classic "20 log(distance)" relationship. The committee settled on this method, as using anything else would be very complicated and depend on many parameters related to the ocean water and bottom. Further, many elements of the standard help insure spherical spreading is correct including: the short distances between the ship and hydrophones, large water depth and use of multiple hydrophones.

The "Post Processing" section also describes how data from three hydrophones (Grades A & B only) are combined into one data set for each run and then how multiple data sets are combined into one resulting sound pressure level (SPL) relative to 1 microPascal at 1 meter as a function of one-third octave bands. These results may then be compared with data from other ships or underwater noise criteria such as that found in the International Council for the Exploration of the Sea (ICES) Cooperative Research Report for fisheries research vessels.[2]

During the development of ANSI/ASA S12.64/Part 1, the Working Group discussed the need to expand the project to address additional issues and it was agreed that these would be addressed in additional parts of the standard or as new Annexes in future revisions of Part 1. These areas include: a measurements application guide (likely to be an informative annex), narrowband measurements, shallow-water measurements, and Arctic underwater noise measurements. At this writing, a new project group is being formed in WG-S12-47 to address shallow water measurement of sound from ships. This is particularly important to Europe since most coastal areas of European countries do not have waters as deep as found off the coast of the United States. If you are interested in contributing to this or any of the other topics mentioned above, contact the author.

Lastly, the author acknowledges all the members of Working Group S12-47 including the committee vice chair Dr. David Vendittis for contribution to this new standard. The author thanks ASA Standards Manager Susan Blaeser for her guidance in getting this new standard off the ground.**AT**

References

1. ANSI/ASA S12.64-2009/Part 1, *American National Standard Quantities and Procedures for Description and Measurement of Underwater Sound from Ships- Part 1: General Requirements*, Introduction (American National Standards Institute, New York).
2. MITSON, R. B. "Underwater Noise of Research Vessels", International Council for the Exploration of the Sea, Cooperative Research Report (CRR) No. 209, 1995.

Oscar (l) and Michael (r) at the first underwater noise survey of the FRV-40 First-In-Class OSCAR DYSON in the Gulf of Mexico, September 2004.

Michael A. Bahtiarian has worked in the field of marine noise control for most of his 24-year career, which started at General Dynamics Electric Boat Division. He is currently the vice president of Noise Control Engineering, Inc. in Billerica, Massachusetts, which specializes in shipboard noise and vibration control. Michael is also a Board Certified member of the Institute of Noise Control Engineering (INCE) and holds a B.S. in Mechanical Engineering from The Pennsylvania State University and a M.S. in Mechanical Engineering from Rensselaer Polytechnic Institute. Mr. Bahtiarian is the chairman of the ASA Working Group S12-47 which produced ANSI S12.64. He has completed numerous shipboard noise control projects most notably the NOAA Fisheries Research Vessel (FRV-40), (First-In-Class *OSCAR DYSON*); and the *R/V HUGH R. SHARP*, a quiet research vessel for the University of Delaware.