Guidelines for Underwater Noise from Ships and Trends in the IMO, Etc.

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1. INTRODUCTION

In January of this year, ClassNK (hereinafter, the Society) held the ClassNK R&D Forum (hereinafter, the Forum) to hear the various needs of persons in the maritime industry, etc. related to services and research and development, and to create opportunities for the creation of new collaborations such as joint research, etc. As a theme of presentations at the Forum, the Research Institute addressed the issue of underwater noise generated by ships, which has attracted heightened interest worldwide as a new environmental problem. This article summarizes the presentations on “Trends in Discussions on Reduction of Underwater Radiated Noise from Commercial Shipping in the IMO” and “Response to Guidelines for Underwater Noise from Ships.”

This article presents an outline of the history of the establishment of the IMO’s guidelines on underwater noise, the characteristics of underwater noise, trends in initiatives to reduce underwater noise from ships in each country, guidelines issued by the Society and other ship classification societies, technical issues for reduction of underwater noise from ships and the future initiatives of the Society.

2. HISTORY OF ESTABLISHMENT OF GUIDELINES ON UNDERWATER NOISE BY THE IMO

In the early 2000s, there was a growing concern about the impact of underwater noise on marine life and on marine acoustic equipment used by the oil and gas industry for subsea oil field development, etc. The IMO discussed the reduction of underwater noise levels emitted from commercial ships. At MEPC 58 held in 2008, the United States proposed the development of guidelines (MEPC 58/19) for underwater noise from ships due to propeller cavitation and engine vibration, including consideration of noise control measures at the design stage and improvement of operational procedures, but the guidelines were not obligatory due to various issues related to underwater noise measurement methods and noise control for large merchant ships. The first IMO Guideline for the Reduction of Underwater Noise from Shipping to Address Adverse Impacts on Marine Life (MEPC.1/Circ.833) [1] was approved at MEPC 66 held in 2014.

3. CHARACTERISTICS OF UNDERWATER NOISE

Underwater noise can be broadly divided into structural noise, which occurs when the vibration caused by the main engine, auxiliary engines, etc. installed in a ship propagates through the hull structure and is radiated from the hull shell plates, and propeller noise caused by fluid noise due to friction between the hull and a fluid, etc. or propeller cavitation (Photo 1) [2]. Propeller cavitation occurs by a process in which the pressure on the propeller blade surface decreases as the blade passes through the area near the hull where the flow is slow, generating a huge volume of cavitation bubbles locally, and the bubbles grow and then undergo a rebound action of compression and collapse. Wide bandwidth noise is generated when this occurs. In addition, because the propeller blades pass periodically, peaks at the harmonic components of the frequency of propeller blade passage (i.e., number of blades x rotational speed) are caused by fluctuations in the volume of cavitation.

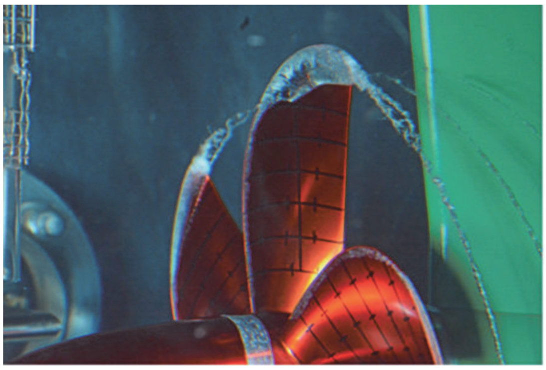

Photo 1　Cavitation caused by ship propeller (tank test)

Particularly in the case of large-scale blunt ships, which have a highly irregular stern flow and require a high-efficiency propeller, ship underwater noise caused by the propeller and radiated in the water is dominant. In the case of research ships, warships, and others in which low underwater noise itself is a performance requirement, it is possible to take countermeasures to reduce structural noise, for example by providing vibration-isolating mounts for the main engine, adopting electric propulsion, etc. However, the majority of ships built in Japan are large-scale blunt ships, in which the main engine and other engines, which have a large vibratory force, are mounted directly on the hull, and it would be difficult to take countermeasures such anti-vibration supports, etc. It should also be noted that the noise caused by the main engine, etc. becomes apparent if cavitation noise is reduced by decreasing the ship's speed.

In water, the sound at high frequencies of 1 000 Hz and higher attenuates greatly and does not travel long distances. However, much of the sound generated by ships is low frequency sound, so almost no attenuation effect in water can be expected. Because the speed of sound in water is affected by the water temperature, underwater sound generally tends to deviate toward the sea bottom due to the temperature distribution in oceans. The general propagation distance is considered to be several km to several 10 km. However, when the water temperature distribution and the sound velocity change with the water depth, there is a region in this distribution called a "sound channel" where the sound velocity reaches its minimum, depending on the season. Due to refraction, the sound waves do not radiate in the vertical direction, but approach a condition of diffusion within cylindrical coordinates. In this result, the sound waves can affect marine life even at great distances.

The effects of underwater noise from ships on marine life include changes in behavior and decreased auditory sensitivity of the organisms affected, and in extreme cases, underwater noise can damage the auditory organs and affect the habitat distribution area, migration routes, etc. As shown in Fig. 1, the frequencies at which various species are easily affected by underwater noise differ depending on the species [3].

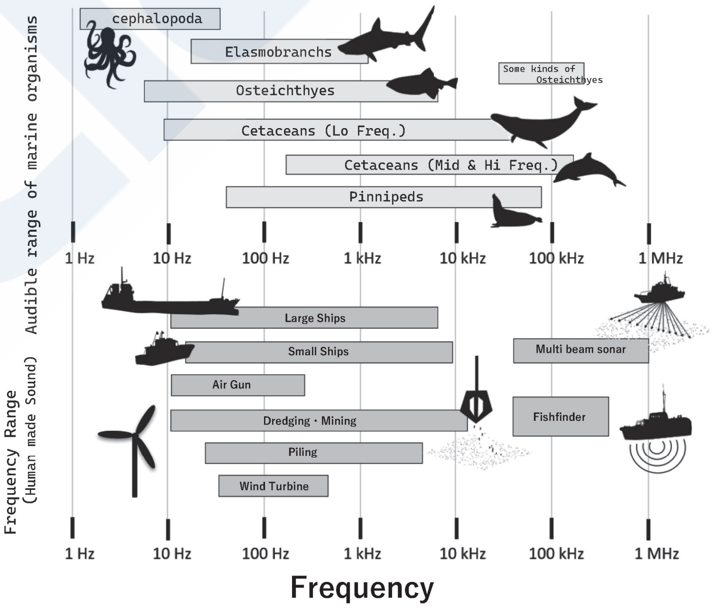

Fig. 1　Underwater noise and audible ranges of marine life

4. SHIP CLASSIFICATION SOCIETY GUIDELINES FOR UNDERWATER NOISE

Eight ship classification societies have issued guidelines for underwater noise from ships corresponding to the IMO Guidelines approved in 2014 (hereinafter, the 2014 Guidelines). ClassNK (the Society) issued “Guidelines for Underwater Noise from Ships (Edition 1.0)” in October 2023.

These Guidelines consist of six chapters covering design requirements, measurement of underwater noise, survey, etc., and appendices summarizing examples of underwater noise reduction measures, etc. As in the Guidelines issued by other ship classification societies, the ClassNK Guidelines contain provisions conforming to ISO 17208-1 and -2 for acoustic measurement and evaluation in deep seas, where the effect of sound reflection by the sea bottom is limited. the Society specifies that the water depth is to be 150 m or 1.5 times the ship’s length, whichever is greater (Fig. 2), and the position of the hydrophone array and the route of the target ship (Fig. 3), and notations (SUN-Controlled, SUN-Advanced) are affixed to the ship’s classification characters based on original standard noise levels (Table 1 and Fig. 4).

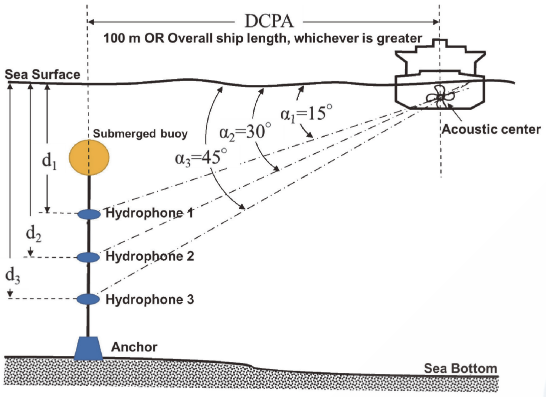

Fig. 2 Example of arrangement of bottom-mounted hydrophones

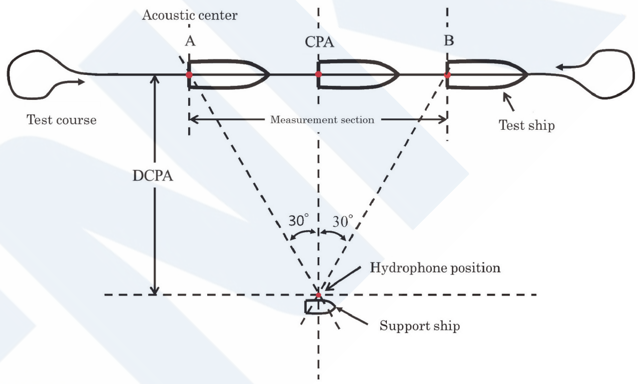

Fig. 3 Measurement configuration (test course, etc.)

Table 1 Reference noise levels (1/3 octave band)

Frequency	Critical sound pressure level (1/3 octave band) *dB* re 1µPa @1m			
f(*Hz*)	**SUN-Controlled**		**SUN-Advanced**	
20	175	SPL = 4.365 × LN(f) + 161.9	160	SPL = 4.365 × LN(f) + 146.9
50	179		164	
100	173	SPL= −8.288 × LN(f) + 211.3	158	SPL = −8.288 × LN(f) + 196.3
1,000	154		139	
10,000	135		120	

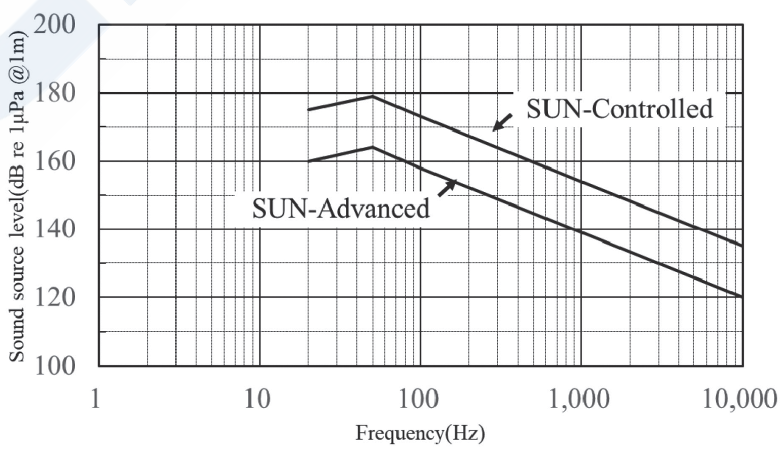

Fig. 4 Reference noise levels (1/3 octave band)

5. RESEARCH TRENDS, ETC. RELATED TO UNDERWATER NOISE FROM SHIPS AND DISCUSSIONS ON REVIEW OF THE IMO GUIDELINES

5.1 Trends in Research on Underwater Noise from Ships by Country

In the EU, two research projects related to underwater noise from ships, SATURN and PIAQUO, have been carried out.

SATURN is based on the perspective that environmental pollution by underwater radiated noise (URN) from ships may possibly interfere with communication, foraging and avoidance of predators by marine life, and consists of an interdisciplinary team centered on experts in bioacoustics. The purposes of the project comprise the following three items:

- To deepen understanding of the sources of URN and how they affect various marine species.
- To identify the effects of URN on marine ecosystems (including both short- and long-term effects).
- To develop solutions for mitigating these effects and reducing environmental pollution by URN.

The targets of research include measurement of the effects of URN from ships on marine life, development of standards and test methods for assessing those effects, and quantification of URN from commercial shipping and other types of ships, etc. As outcomes of this research, the project has published a report [4] on measurement of URN in shallow waters, which will be important for ensuring the effectiveness of URN management in the future, and a paper [5] showing that only a slight reduction in the speed of cargo ships greatly reduces the effects of noise on marine mammals.

PIAQUO is a project that began in 2019 with the aim of mitigating the impacts of noise caused by marine traffic on marine life by minimizing underwater noise pollution. This project centers on manufacturers, research institutes, etc. which conceive solutions that realize reductions in underwater noise. Companies [6] and others that develop and manufacture warships, sensors mounted on warships, etc. and have particularly strong expertise in underwater acoustics are also participating.

The main goals of the PIAQUO project are as follows:

- To develop improved propellers to reduce emissions of underwater radiated noise.
- To develop onboard systems for self-estimation of the level of URN generated in the surrounding environment and self-detection of cavitation in real time.
- To create a program targeting ship owners with the aim of raising awareness of reduction of emissions of URN, using a database that includes actual sound pollution data measured by acoustic buoys at sea.
- To create a mechanism for adjustment of marine traffic to the surrounding maritime ecosystem, by using real-time PAM (passive acoustic mapping) and AUV (autonomous underwater vehicles).
- To realize social implementation of decision-making tools for public institutions and private-sector stakeholders in order to address the problem of URN from ships.

The project has also presented a future image of underwater noise management which will integrate stationary buoys, shipboard systems and AUVs when these goals are achieved [7].

As outcomes of the project, evaluations of underwater noise from individual ships passing nearby by a stationary buoy installed in the Port of Genoa have already been carried out. The concept of the Noise Ship Index (NSI) was also developed by the project, and use of the NSI for tracking and recognition of the condition of URN, the condition of the progress of countermeasures, etc. as required by ship owners and managers is being considered [8].

In Canada, URN from ships calling at the Port of Vancouver is measured and evaluated on an ongoing basis. Reduction of ship URN is incentivized by the EcoAction Program [9], which gives preferential treatment such as reduction or exemption from the ship's harbor charges to quiet ships. When a ship classification society has assigned a notation indicating URN reduction measures, 75% of harbor charges will be reduced, the maximum rate of exemption available. In addition, the installation of propellers and other equipment manufactured by Japanese domestic manufacturers is also eligible for the exemption.

In Japan, the "Underwater Noise Countermeasures Study Project" has been underway since 2015 by the Japan Ship Technology Research Association (JSTRA) as part of "Survey Research on Ship Related Standards," a supported project of the Nippon Foundation. Various types of demonstration research are being carried out as part of this project. As one example, a study on the response behavior of humpback whales when ships pass was carried out by visual observation and acoustic measurement in the waters around Chichijima in the Ogasawara Islands, where regularly-scheduled passenger and cargo ships operate. As results of this study, it was suggested that it is difficult to think that exposure to the noise of the target ships caused damage of the auditory organs of the whales, and based on the results of an analysis of their behavior, it was not possible to obtain a clear conclusion that exposure to the ship noise had an adverse impact on their mode of life. A hydrophone array was also installed in the waters near Izu Oshima island, which has a water depth of approximately 300 m and is a navigation route for large merchant ships, and the underwater reflected noise levels from about 500 passing ships were acquired. The source levels were then obtained based on AIS information on the passing vessels and information on the seawater temperature distribution in the depth direction on the day of the measurement. That data has become the basic data for formulation of the reference noise levels of the Society's "Guidelines for Underwater Noise from Ships."

5.2 Discussions on Review of Guidelines for Underwater Noise

The 2014 Guidelines, once established, have not been adopted and implemented on a sufficient number of large merchant ships,, as well the accumulation of new technical innovations and scientific knowledge since that time, a new work program item (MEPC 75/14) proposed by Canada, Australia and the United States was discussed at MEPC 76 in 2021. In addition, 14 proposals were also submitted by a number of environmental groups and member countries, including European countries. As a result, a decision was made to begin a review of the existing 2014 Guidelines and deliberations on the subsequent action plan in the Sub-Committee on Ship Design and Construction (SDC). At the same time, a study on implementation of a global-scale project for mitigation of underwater noise from shipping (GloNoise Partnership) was also begun under the leadership of the IMO.

Following discussions over a 2-year period, the Revised Guidelines (MEPC.1/Circ.906; hereinafter, 2023 Guidelines) were adopted at MEPC 80 in 2023, targeting all commercial ships (cargo ships and passenger ships, new and existing ships) [10].

In addition, An "Experience-building phase (EBP)" until the end of 2026 was set, mainly to collect feedback on the Revised Guidelines, information related to best practice, and information for establishing mechanisms to realize noise reductions.

5.3 Overview of 2023 Guidelines

The largest change in the 2023 Guidelines was inclusion of provisions for the preparation of Underwater Radiated Noise (URN) Management Plans to ensure the effectiveness of reductions in underwater noise radiated from shipping. The main items described in those provisions are as follows.

- Setting of the baseline URN level (may be predicted or preferably measured)
- Setting of the target URN reduction level (can be gradually strengthened over a specified period)
- Description of URN reduction approaches, i.e., what technical and operational actions are to be taken by the ship
- Periodic monitoring and evaluation of the effects of URN reduction actions
- Roles of main parties related to the URN Management Plan

Under the 2014 Guidelines, the only stakeholders that made commitments to reduce URN were ship designers, manufacturers and operators. However, the 2023 Guidelines expanded the stakeholders as follows and specified their roles.

- Shipowners: Develop and implement the URN Management Plan.
- Shipbuilders: Design and build the ship to meet URN specifications.
- Ship operators: Operate the ship to meet URN targets and any additional regional requirements.
- Maritime authorities of the flag state: Take supportive actions in the form of incentives.
- Ship classification societies: Assist shipowners and builders through predictions of URN, URN measurement and testing in actual waters, certification, etc.

Workflow charts for implementing these provisions have been compiled by the IMO. An excerpt is shown in Fig. 5.

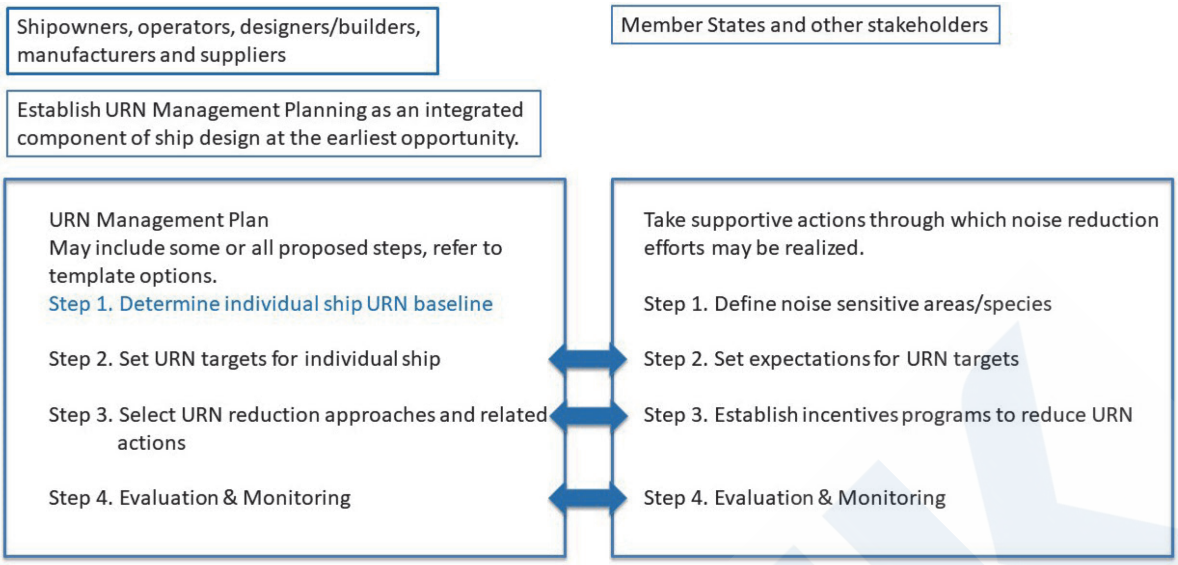

Fig. 5 Workflow chart of 2023 Guidelines (excerpt)

6. RESPONSE OF THE SOCIETY TO THE 2023 GUIDELINES

The 2023 Guidelines state that the role of ship classification societies is to “assist shipowners/builders through predictions, trials, relevant URN notations, certification, etc. as reasonable and practicable.” Classification societies are expected to participate in each of the Steps of URN Management Planning on the left side of Fig. 5. Here, Step 1 Determine the baseline URN of the individual ship, specifies that “The baseline URN is to be predicted or preferably actually measured under normal operating conditions using the standard equipment/engines.” The 2014 Guidelines followed the measurement method in ISO 17208-1, -2 for measurements in deep waters, where the effect of sea surface reflection, etc. is slight. However, examples of measurements of large merchant ships were limited, as there is no economic incentive due to the high cost of such measurements. In the future, it is considered likely that measurements will conform to the URN measurement method in shallow waters described in ISO 17208-3, which is reasonable and economically practicable. Formal approval of ISO 17208-3 is expected during 2025. However, there are issues related to measurement accuracy, such as elimination of the effect of sea surface reflection, calibration of the trial sea surface, etc. For a discussion of the technical issues related to URN measurement in shallow waters, please see “Measurement of Ship Noise in Shallow Water” in this issue of ClassNK Technical Journal.

Appendix 2 of the 2023 Guidelines presents the following items as types of computational models for optimization of ship design and technical URN reduction approaches.

1. Flow characteristics (fluid noise): Underwater radiated noise generated by cavitation, etc. can be predicted by techniques for analysis of flow field around the ship’s hull and propeller performance using CFD, etc.
2. Noise radiation (structural noise): URN originating from the main engine, etc. can be predicted by using analytical techniques such as FEM, BEM, SEA, etc.
3. Noise propagation in water: The effect of URN from a ship on the targeted marine species, etc. can be predicted by long-range sound propagation modelling methods such as ray theory, the normal mode method, etc.

Since these techniques are also in a region which is closely related to military applications, represented by anti-submarine warfare, care is considered necessary so as not to introduce excessive regulations for general commercial ships based on the advanced military technologies. The Society has carried out a study on a simple estimation method for flow characteristics in 1. above. For a commentary on the results of that research, please see “Development and Use of Ship Underwater Noise Prediction Tool for Preservation of the Marine Environment” in this issue.

Although the Society will also carry out work on each step of the URN Management Plan from Step 2 to Step 4 in the future, the basic concepts are as follows.

Step 2. Set desired values for target URN:

Since the reduction target from the baseline URN is specified by setting an absolute reduction value, a reduction ratio, or other values that conform to the rules of the classification society for underwater noise from ships, etc., the Society will collect and disseminate relevant information.

Step 3. Establish an incentive program for URN reduction:

The Guidelines specified that a design approach, operational technologies, or a combination of those approaches is to be identified and selected. The Society plans to study assigning notations to the classification characters of ships that install hull appendages, adopt optimum operational techniques, etc. for URN reduction.

Step 4. Evaluate and monitor effects:

The Guidelines specify periodic evaluations of the effectiveness of URN reduction approaches, and a response when necessary. Therefore, the Society will study certification of shipboard URN monitoring systems, standardization of hull cleaning, etc.

At present, there is a feeling that the eventual form of regulations on URN is still unclear. However, as a ship classification society, ClassNK will continue to deepen its dialogue with related stakeholders, develop methods, tools, etc. that are "reasonable and practicable," and endeavor to resolve the concerns of stakeholders regarding underwater radiated noise from shipping.

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