GUIDANCE NOTES

GD022-2024

CHINA CLASSIFICATION SOCIETY

GUIDELINES FOR UNDERWATER RADIATED NOISE OF SHIPS

2025

Effective from 1 January 2025

Beijing

Contents

Chapter 1 General

1.1 Scope of application

1.1.1 The purpose of the Guidelines is to provide classification requirements for underwater radiated noise of ships, and procedures and technical requirements for measurement.

1.1.2 The Guidelines are applicable to ships applying for CCS class notation in 1.2 below to perform the essential service functions by operating hydro-acoustic equipment and ships required to reduce the impact of underwater radiated noise on the environment.

1.1.3 The underwater radiated noise is to be measured by CCS or by a firm approved by CCS. The measurement process is to be witnessed by a CCS surveyor.

1.1.4 For underwater noise control during the ship design, construction, modification and operation stages, reference can be made to Appendix 2 of the Guidelines.

1.1.5 If the ship has undergone a major conversion that may affect the ship's underwater radiated noise, the class notation specified in the Guidelines is to be reconfirmed.

1.2 Class notations

1.2.1 Ships that have been measured to meet the requirements of Chapter 2 of the Guidelines may be assigned the following class notation for underwater radiated noise of ships:

Underwater Noise N

N means underwater radiated noise level, N=1, 2 or 3, in which 1 represents the highest level of underwater radiated noise.

1.2.2 The class notation for underwater radiated noise of ships may be assigned in frequency bands (10-100Hz, 100-1000Hz, 1000-100000Hz) if only the requirements of the specified frequency band are satisfied, which is to be indicated in the class notation.

1.3 Requirements for documentation

1.3.1 The noise measurement program is to be submitted to CCS for approval prior to the measurement of underwater radiated noise of ship. The measurement program is to at least include the following:

① Measurement equipment, such as acoustic measurement equipment, distance measurement equipment, speed measurement equipment, etc.;
② Measurement conditions, including the location of the sea area under test, the water depth of the sea area under test and the conditions of the seabed, and the information of the sea conditions (such as wind, waves, etc.);
③ The operation status of the ship under test, such as speed, pitch and power of propeller or side thrust; main engine power and speed; ship speed; loading condition of the ship;
④ Measurement procedure, such as hydrophone arrangement, ship's sailing path, etc.

1.3.2 After the measurement is completed, the measurement report is to be submitted to CCS for approval. The measurement report is to include at least the following:

① Measurement equipment;
② Measurement conditions, the operation status of the ship and list of running equipment;
③ Differences with the measurement program, such as required measurement conditions, ship operation status, measurement procedure, etc.
④ Background noise spectrum, background noise correction method;
⑤ Result and criterion of sound source frequency band sound pressure level of one-third octave band.

1.4 Symbols and definitions

1.4.1 Source level L_S : a property of a sound source related to its radiated power that can be determined by adding propagation loss (which should include the related water column and, for shallow waters seabed characteristics) to the measured mean square sound pressure level. $L_S = L_p + N_{PL}$ We consider hereby the ship as a monopole noise source, to be corrected for the water surface reflections.

1.4.2 Sound pressure level L_p : a property of the radiated sound field at a specified location. Measured by an hydrophone it equals to the root-mean-square sound pressure level: $L_p = 20\log_{10}\left(\frac{p_{rms}}{p_0}\right)$, p_0 being the reference sound pressure equals to $1\mu P_a$.

1.4.3 Background noice level L_{BN} : combination of ambient noise and acoustic self-noise, dB, reference sound pressure: $1\mu P_a$.

1.4.4 Propagation loss N_{PL} : a transfer function defined as the difference between source level and sound pressure level. It should include the related water column and, for shallow waters, seabed characteristics.

1.4.5 Radiated noise level L_{RN} : $L_{RN} = L_p + 20\log_{10}\left(\frac{d}{d_0}\right)$; d being the distance (in m) between ship reference point of a sound source and the specific location, d_0 being the reference distance, equals to 1m.

1.4.6 Decidecade: one tenth of a decade i.e $0.1\log_2(10)$.

1.4.7 Acoustic center: virtual point representing the ship as the source under freefield conditions. For a ship it is to be considered as follows:

- in the longitudinal direction: halfway between the main engines center and the propeller
- in the vertical direction: at 0.7 of the vessel draught from waterline.

1.4.8 Closest point of approach:this is the point, during a test run, point where the reference acoustic centre of the vessel under test is the closest to the hydrophones. The practical use is the corresponding distance d_{CPA}.

1.4.9 One-third octave band: frequency interval is used to represent the interval or frequency band width between two frequencies of sound, expressed in terms of the logarithm between the upper limit frequency f_u and the lower limit frequency f_l; this logarithm is usually based on 2, in octave, i.e.:

$$n = \log_2\left(\frac{f_u}{f_l}\right)$$

When $n = 1/3$, it corresponds to one-third octave band.

1.4.10 Sound pressure level radiated by sound source L_{p1m} : the sound pressure level at a distance of 1 m from the equivalent sound center obtained by conversion, in dB.

1.4.11 Transmission loss (L_T): the transmission loss of sound wave in seawater medium. The sound pressure decreases with the increase of distance from the sound source and the transmission loss increases with the increase of distance from the sound source. Assuming that position 1 is closer to the sound source than position 2, the transmission loss is:

$$L_T = 20\log_{10}\left(\frac{p_1}{p_2}\right)$$

where:

P1— sound pressure of position 1, in Pa;

P2— sound pressure of position 2, in Pa;

When the transmission distance between two positions is r, the transmission loss is:

$$L_T = X\log_{10}\left(\frac{r}{r_{1m}}\right)$$

where: r ——distance between the sound source and the hydrophone, to be taken as $\sqrt{D_H^2 + D_V^2}$, in m;

D_H —— distance at the closest point of approach of the hydrophone, in m;

D_V —— Vertical distance from the hydrophone to the acoustic center, in m;

r_{1m} ——At a reference distance of 1 m from the sound source, to be taken as 1 m;

X —— According to the actual real sound field, when the sound wave is transmitted as a spherical wave, 20 is taken. When the sound wave is transmitted as a cylindrical wave, 10 is taken. For a ship, when the water depth d is measured to be more than 100 m, 20 is taken. When the water depth d is not more than 100 m, 18 is taken.

1.4.12 Distance at the closest point of approach (d_{cpa}) : The horizontal distance from the closest point of approach to the hydrophone, in m.

1.4.13 Sound celerity profile: a curve in which the speed of sound varies with the depth of water.

Chapter 2   Criteria for Underwater Radiated Noise

2.1   General provisions

2.1.1   The allowable underwater radiated noise limits of the class notation for underwater radiated noise of ships (Underwater Noise N, N= 1, 2, 3) are specified in this Chapter. For ships which perform the essential service functions by operating hydro-acoustic equipment, the underwater radiated noise limits are given in 2.2. For other ships required to reduce the impact of underwater radiated noise on the environment, the allowable underwater radiated noise limits are specified in 2.5.4, Chapter 2, Part 1 of CCS Rules for Green Eco-ships.

2.1.2   The measurements are to be carried out under the conditions that can represent the typical or expected navigation state of the ship.

2.1.3   The one-third octave band frequency band sound pressure level of underwater radiated noise of ships is to be measured. Background noise correction and distance correction are to be carried out for each hydrophone and each sub-data window, and the radiated noise sound pressure level L_{p1m} at a distance of 1 m from the equivalent sound center is to be obtained by conversion. Subsequently, energy averaging of all hydrophones, linear averaging of all sub-data windows, and the linear averaging of all voyages are to be carried out to finally obtain the underwater radiated noise level of the measured ship.

2.2   Underwater radiated noise limits

2.2.1   The sound pressure level of the radiated noise from the sound source is to be calculated according to the following formula:

$$L_{p1m} = L_p^{'} + L_T$$

where:

L_{p1m} — sound pressure level of the radiated noise from the sound source, in dB;

$L_p^{'}$ — sound pressure level of each hydrophone and each sub-data window after background noise correction, in dB;

L_T — propagation loss, calculated according to 1.4.11.

2.2.2   The underwater radiated noise limit is one-third octave band frequency band sound pressure level, as shown in Figure 2.1.

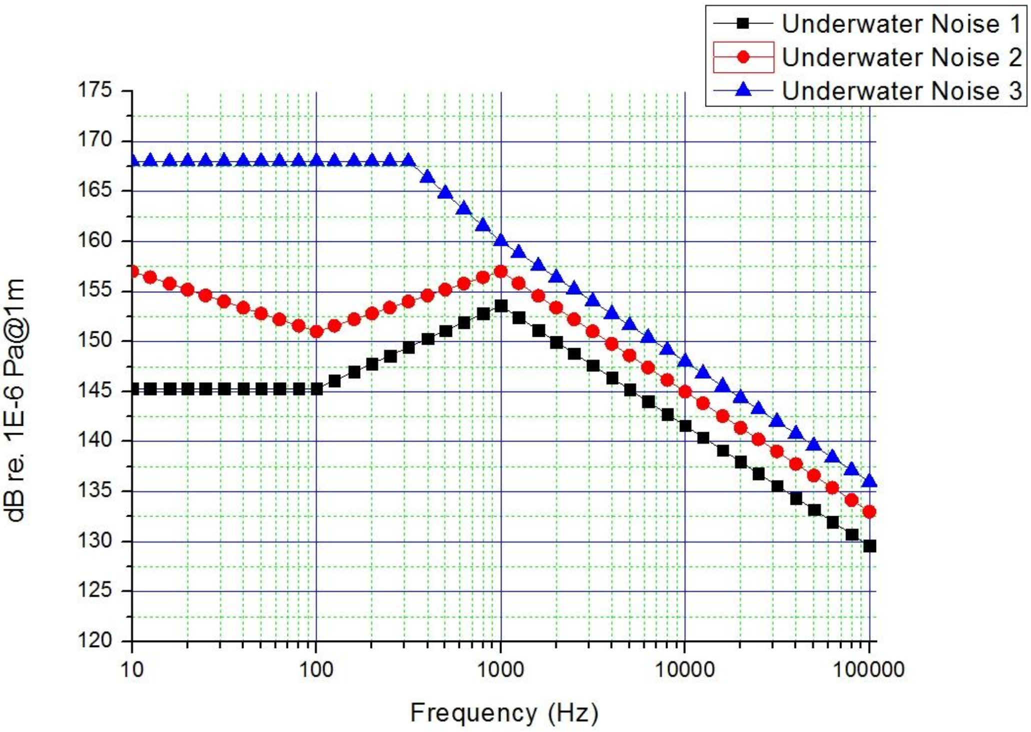

Figure 2.1 Underwater radiated noise limits

2.2.3 See Table 2.1 for the formula of underwater radiated noise limits.

Underwater radiated noise limits **Table 2.1**

Class notation category	Limit criteria dB (reference sound pressure 1μPa)	Frequency range
Underwater Noise 1	145.3	10 Hz-100 Hz
Underwater Noise 1	128.7+8.3 lg f(Hz)	100 Hz-1kHz
Underwater Noise 1	153.6-12 lg f(kHz)	1 kHz-100 kHz
Underwater Noise 2	163-6 lg f(Hz)	10 Hz-100 Hz
Underwater Noise 2	139+6 lg f(Hz)	100 Hz-1kHz
Underwater Noise 2	157-12 lg f(kHz)	1 kHz-100 kHz
Underwater Noise 3	168	10 Hz-315Hz
Underwater Noise 3	208-16 lg f(Hz)	315Hz-1 kHz
Underwater Noise 3	160-12 lg f(kHz)	1 kHz-100 kHz

Note: f——one-third octave band center frequency

Chapter 3 Measurement of Underwater Radiated Noise

3.1 General requirements

3.1.1 The Guidelines address safety concerns and experience of working in situ with large ships in open waters.

3.1.2 The Guidelines are intended to harmonise and present a single method for the measurement of underwater radiated noise and detail a consistent analysis/post processing means and reporting standard.

3.2 Scope

3.2.1 The Guidelines address the measurement of continuous underwater radiated noise from ships using three omni-directional hydrophones.

3.2.2 Other anthropogenic underwater noise such as impulsive noise from pile driving or coastal civil engineering activities, active sonars, seismic surveys or produced via other activities such as dredging, tunnelling etc. are not considered in the Guidelines.

3.3 Test Site Conditions

URN measurement procedures rely on the deployment of in water measuring equipment. Thus, manned operations at sea are to be undertaken safely and securely. Further, the quality and robustness of data collected during URN measurement is often influenced by external factors that can affect the sound measurement consistency, including meteorological and weather conditions, local/nearby marine traffic and overall site topology. Therefore, the conditions, as specified below, are recommended:

3.3.1 Weather conditions:

Weather conditions are not to exceed:

(1) Wind: Beaufort wind force 4
(2) Sea State: 3

Rainy conditions are to be avoided due to background noise generation.

Additional information that is to be reported includes:

(1) effective wind speed and direction,
(2) effective sea state,
(3) ship heading during the test.

3.3.2 Tides and current

Measurements are not to be carried out where currents exceed 2 m/s.

The following current information is to be reported:

(1) speed and direction
(2) tide related data

3.3.3 Minimum water depth

The minimum water depth should is to the greater of 60 m or $0.3v^2$.

where v = vessel speed over bottom in m/s.

Measurement in water of depths between 60 and 40 m may be taken provided due account is made for the frequency limitation (cut-off frequency):

Table 3.1 Cut-off frequency relatively to water depth assuming a constant sound speed in water of 1490m/s and a sandy seabed sound speed of 1790m/s

Water depth (m)	10	20	30	40	50	60	70	77	80	90	100	200	300
Cut-off frequency (Hz)	77.1	38.5	25.7	19.3	15.4	12.8	11.0	10.0	9.6	8.6	7.7	3.9	2.6

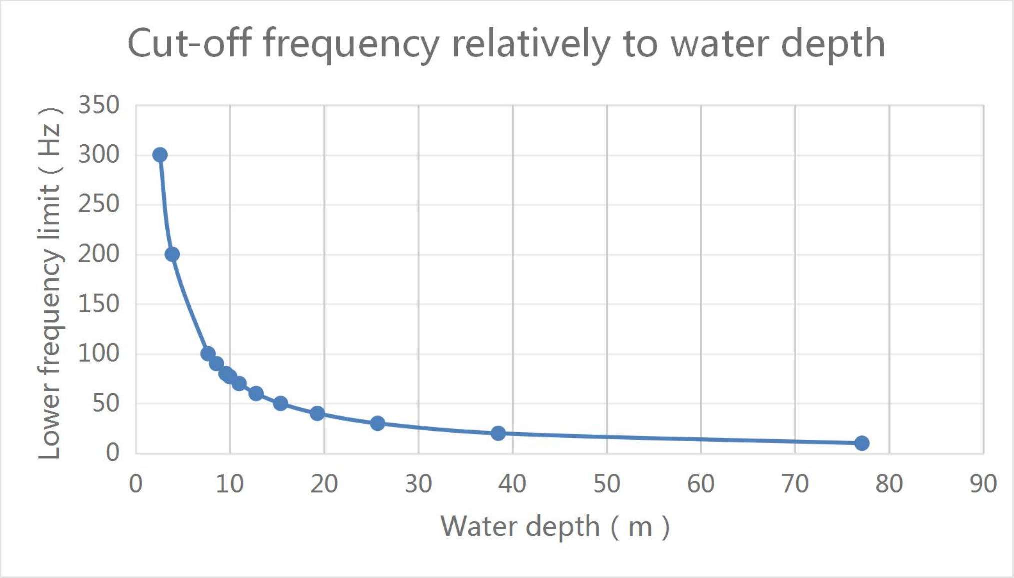

Figure 3.1 Cut-off frequency relatively to water depth assuming a constant sound speed in water of 1490m/s and a sandy seabed sound speed of 1790m/s

Measurements are not to be taken in water with a depth of less than 40 m. For measurements taken in a water depth of less than 60 m, refer to 3.5.1.

3.3.4 Sea bottom profile

The nature of the sea bottom is to be recorded. Where possible the sea bottom is to be flat.

3.3.5 Background noise

Background noise is to be eliminated to the extent possible. The test site is to be as far as possible from vessel traffic lanes, port in/out lanes, marine works such as dredging, pile driving, fishing or diving zones, seismic exploration, mine clearing activities or coastal civil engineering works.

3.4 Instrumentation and data acquisition

3.4.1 Underwater acoustic measurements

3.4.1.1 Number of hydrophones

Three omni-directional hydrophones are to be used.

3.4.1.2 Hydrophone sensitivity uncertainty

A maximum uncertainty of ±2.5 dB within the frequency range of the measurements is to be observed.

3.4.1.3 Measurements line array geometry:

The hydrophone vertical array line is to be linked to a free-floating surface buoy which is uncoupled from the sea surface. Additional mooring features are also to be considered when appropriate.

The hydrophone line is to be bottom mounted. A free-floating line may be considered when water depth prevents the deployment of bottom mounted lines. The vertical arrangement of hydrophones is to be defined to ensure measuring the beam aspect of the tested vessel. The arrangement is to be reported.

3.4.1.4 Distance measurement:

The ship reference point is to be taken at the centre line, at the middle between propeller and engine(s) arrangement and vertically at the nominal source depth defined at 0.7 times of the ship’s draft.

The constantly changing distance between the reference acoustic centre of the tested vessel and each of the hydrophones is to be recorded. Distances are to be measured with an accuracy of ±10m. The use of DGPS (Differential Global Positioning System) is recommended. Tilt angle measurements of the hydrophone array line are recommended to optimize the accuracy.

3.4.1.5 Water column speed properties:

To be able to calculate the propagation loss via numerical modelling, the celerity profile of the water column is to be ascertained. This is to be performed using either a CTD (conductivity, temperature, depth) measurement device or via a direct sound speed sensor.

The following non-exclusive numerical modelling methods for characterizing propagation losses may be used:

(1) Parabolic waves equations

(2) Scooter/Fields model (wave integration model) for low frequencies (below 1000Hz)

(3) Bounce or Bellhop model (ray trace-based model) for higher frequencies

To take into account that the vessel is a moving noise source, the modelling propagation loss is to be range-average smoothed. Onsite direct sound speed measurements covering the whole range of frequencies for the test may be considered as an alternative to modelling.

3.4.1.6 Other parameters to be measured and reported

The tested vessel speed and location are to be measured using onboard systems or dedicated DGPS (Differential Global Positioning System) ensuring a minimum accuracy of ± 10m.

In addition, seabed characteristics are to be considered in the modelling especially in case of shallow waters.

3.4.1.7 Calibration

Calibration of underwater acoustic measurement equipment are to be carried out using IEC 60565-1:2020 and/or IEC 60565-2:2019. The calibration of hydrophones is to be undertaken by an external recognized lab every 24 months at maximum and as recommended by the hydrophone manufacturer. In addition, an in-situ check of the whole system using a dedicated calibrator (e.g., pistonphone) is to be performed prior and after the measurements. This calibrator is to be calibrated every 12 months at maximum.

The data acquisition system is to be laboratory checked every 24 months at maximum. The measuring celerity profile device is to be calibrated every 24 months at maximum.

3.5 Data acquisition and recording

The instrumentation set-up is to ensure, during the test legs, synchronous acquisition, recording and processing of:

(1) sound pressure measurements from hydrophones

(2) distance between tested vessel and hydrophones

(3) tested vessel speed over ground.

Other measurements (calibration checks, celerity profile…etc.) are to be recorded.

3.5.1 Acoustic data

The measurement frequency range is to cover, in decidecade bands, the bandwidth 10Hz-50kHz. For research vessels, the bandwidth is required to be 10Hz-100kHz. When it is difficult to measure in the high frequency band (50k-100kHz), estimation can be made based on the measured data in the range of 10k-50kHz .

For measurements taken in a water depth of less than 60 m a propagation model enhanced with actual field characteristics measurements is to be carried out to demonstrate that less than 3dB uncertainty is achieved.

3.5.2 Measurement line deployment

A minimum of three hydrophone on a single line array are to be be used. It is recommended that the deployment method incorporates a line from a buoy decoupled from the sea surface. The hydrophone array is not to be directly coupled to the support vessel to limit not only the noise disturbances caused by the vessel behaviour but also prevent masking from occurring.

For deep water measurements the array is to be arranged as required by ISO 17208-1(2016), see Figure 3.2.

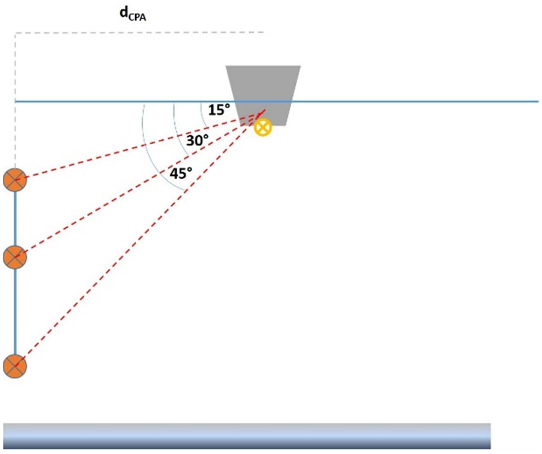

Figure 3.2 Recommended deployment for deep water (ISO 17208-1(2016))

For shallow waters bottom mounted deployment are recommended , see Figure 3.3.

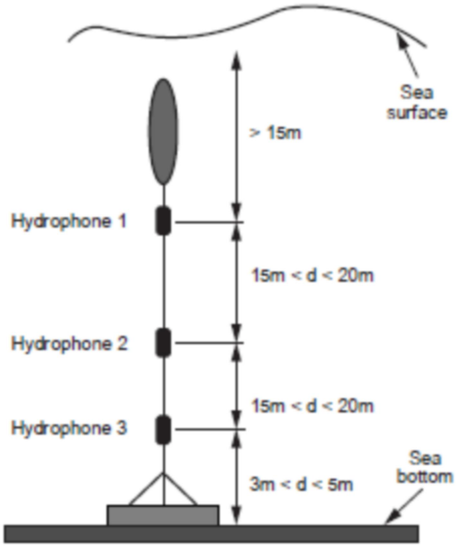

Figure 3.3 Recommended deployment for shallow water

3.5.3 Vessel Transects and closest point of approach (CPA)

3.5.3.1 Distance at CPA (d_{CPA})

The minimum distance at closest point of approach is to be the greater of 200 m or one ship length. For ships with length less than 200 m, a minimum distance of 100 m may be accepted

3.5.3.2 Vessel Transects

A minimum of 4 measurement runs are to be carried out, 2 for starboard side and 2 of port side. Vessel speed, engine power and engine speed are to be recorded . Steady state forward motion is to be achieved by the time the ship enters COMEX and must be maintained until FINEX. This includes no rudder adjustments, no engine load/speed changes, no pitch changes for CPPs, no genset change…etc.

Accounting that, for large ships, the course and speed stabilization to performs 4 runs takes a significant time, the number of vessel runs may be reduced to 2 for ships over 10,000 GT.

If two lines of three hydrophones are used to measure port and starboard simultaneously, the number of runs may be reduced to 2. The vessel under test is to transit a straight-line course to achieve the required distance at CPA for the run in progress. Recording of data is be performed from a minimum of 800 m or 4 minutes before the fore end of the vessel reaches the CPA (this defines the COMEX) to a minimum of 800m or 4 minutes after the aft end of the vessel has passed the CPA (this defines the FINEX).

Before the vessel crosses the starting point (COMEX) of the record, the required machinery operating conditions are to be achieved and in steady state.

The distance between the measurement line and the vessel under test is to be recorded during all the segments (from COMEX to FINEX).

Operating condition of the vessel is to be recorded during the measurements. Operating condition is to correspond to the normal operations of the vessel, i.e., all major equipment including main engine, auxiliary engine(s), AC plant(s), refrigeration plant and sea water pumps, are to be functional during the measurements. Measurements to include as a minimum, vessel speed, equipment power in normal operating condition (percentage of full load).

3.6 Data post-processing

3.6.1 Data post-processing scheme

The data are to be post processed following the ordering/scheme of Figure 3.4 below.

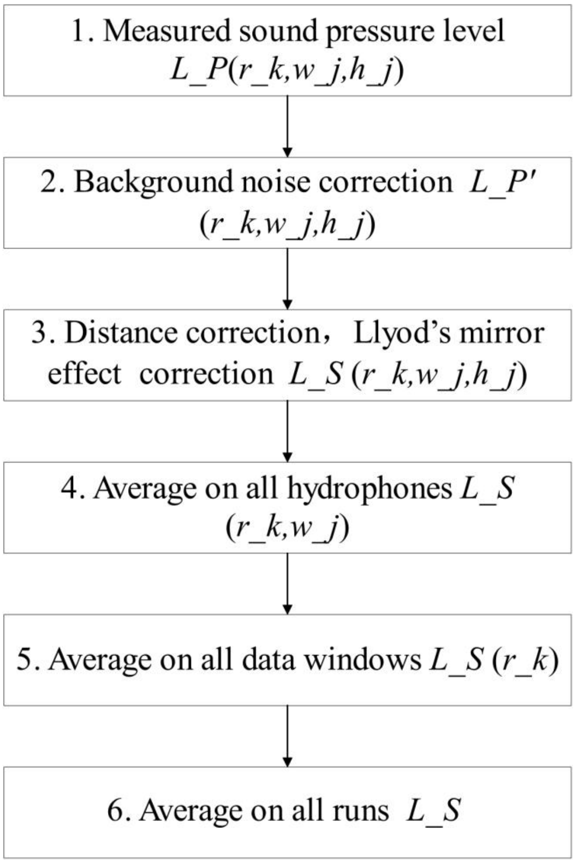

Figure 3.4 Data post-processing scheme

where: r_k —the k-th run;

w_j —the j-th data window

h_i —the i-th hydrophone.

3.6.2 Data windows

Raw time series measurements are to be recorded to permit more detailed analysis including data correction, narrow band analysis as deemed necessary.

The hydrophone data are to be recorded while the ship’s reference point lies within the data window and analysed by dividing it into 10 sub data windows, as shown in the figure below. Each of the sub data windows is to be sized as evenly as possible.

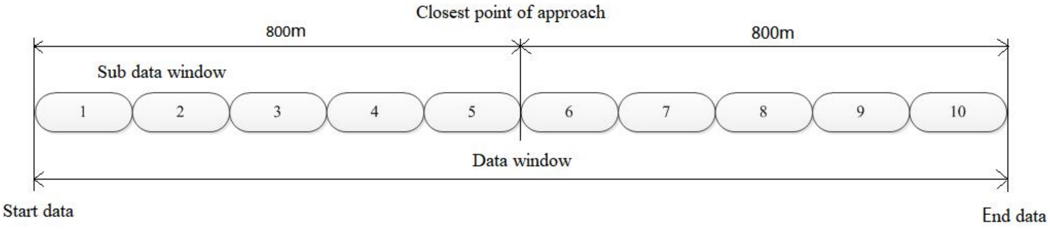

Figure 3.5 Data window subdivision illustration

For each data window, energy averaging of the measured decidecade band sound pressure levels for all hydrophones in each sub-window is to be performed, and then linear averaging is to be performed. A root-mean-square linear averaged decidecade band spectrum of the measured underwater sound pressure level is to be performed for every hydrophone and recorded.

3.6.3. Background noise correction

Each root mean square linearly averaged decidecade band spectrum is to be corrected for background noise according to the following procedure for each hydrophone.

(1) Calculate the arithmetic mean (linear average) of the sound pressure level measured for the hydrophone h_i prior to and after ship test trial. This would be the background noise $L_{BN}\left(h_i\right)$.

(2) Calculate the variation of background noise between the start and end of runs.

(3) Calculate, for each run r_k, data window w_j and hydrophone h_i the signal plus noise:

$$\Delta L\left(r_k, w_j, h_i\right) = L_p\left(r_k, w_j, h_i\right) - L_{BN}\left(h_i\right)$$

If $\Delta L\left(r_k, w_j, h_i\right) \geq 3dB$, the measurement may be considered acceptable with regards to the background noise. The following correction is to be applied:

$$L_p^{'}\left(r_k, w_j, h_i\right) = 10\log\left[10^{\frac{L_p\left(r_k, w_j, h_i\right)}{10}} - 10^{\frac{L_{BN}\left(h_i\right)}{10}}\right]$$

If $\Delta L\left(r_k, w_j, h_i\right) < 3dB$, the measurement is to be rejected.

3.6.4 Calculation of URN

Vessel source level (SL), including Lloyd’s mirror effect correction, is to be calculated and recorded.

The propagation loss $N_{PL}\left(r_k, w_j, h_i\right)$ is recommended to be calculated through modelling enriched with onsite actual water column properties using CTD probes, for each run r, data window w and hydrophone h.

For each run r, data window w and hydrophone h, sound level is to be calculated as follows:

$$L_S\left(r_k, w_j, h_i\right) = L_p^{'}\left(r_k, w_j, h_i\right) + N_{PL}\left(r_k, w_j, h_i\right)$$

3.6.5 Final averaging

Measurements are to be averaged as follows:

(1) sound power average on all (three) hydrophones;
(2) linear average on all data windows;
(3) linear average on all runs.

Appendix 1 Format of Measurement Report of Underwater Radiated Noise of Ships

Measurement Report of Underwater Radiated Noise of Ships

Stamp of measurement organization **Signature of measurement personnel**

1 Basic information			
Measurement location:			Date:
Name of measurement organization:			
Person in charge of measurement:	Telephone:		e－mail：
Name of ship:	Ship registration number:	IMO number:	
Ship type:	Shipyard:	Shipyard number:	Date of construction: Location of construction:
2 Main dimensions			
Length between perpendiculars (m):			
Moulded breadth (m):			
Maximum draft (m)			
3 Propulsion machinery			
Type:		Number of cylinders:	
Quantity:		Maximum rated power (KW):	
Maximum rated speed (R/M):		Installing form:	
4 Auxiliary diesel engine			
Type:		Number of cylinders:	
Quantity:		Rated power (KW):	
Rated speed (R/M):		Installing form:	
5 Thruster			
Type:		Number of blades per propeller:	
Quantity of thrusters:		Nominal pitch:	
Design speed (R/M):		Diameter:	
Other:			
Date of last cleaning of hull and propeller:			
Echo sounder closed (Yes/No):			
6 Underwater radiated noise measurement equipment			
Type of hydrophone:			
Sensitivity of hydrophone:			
Depth of hydrophone deployment:			
Data recording equipment (including sampling rate):			
Preamplifier (if used) :			
Distance measurement equipment:			
Speed measurement equipment:			
Data processing equipment:			
7 Weather conditions at the time of measurement			

Date and start measuring time		
Location (GPS antenna coordinates)		
Sea state		
Wind speed/direction		
Depth of water		

8 Condition of ship

Voyage	Time Start/End	CPA distance	GPS speed (knot)	Speed by log (knot)	Main engine speed of propulsion system		Shafting speed		Propeller pitch		Notes
					Port	Starboard	Port	Starboard	Port	Starboard	
Forward draft:			Midship draft:				Aft draft:				

9 Condition of auxiliary engine

Equipment	Position	Status 1=open 0=closed	Notes

10 Other sound source conditions that may affect the measurement of underwater radiated noise of ships

Type of sound source	Position	

11 Other known issues and concerns that may affect the measurement of underwater radiated noise of ships
12 Sound pressure level of underwater radiated noise of ships

One-third octave band center frequency (Hz)	Sound pressure spectrum source level of underwater radiated noise of ships with one-third octave band frequency band				
	Voyage 1 (average on all data windows)	Voyage 2 (average on all data windows)	Voyage 13(average on all data windows)	Voyage 4 (average on all data windows)	L_{RN} (average on all runs)
10					
12.5					
16					
20					
25					
31.5					
40					
50					
63					
80					
100					
125					
160					
200					
250					
315					
400					
500					
630					
800					
1000					
1250					
1600					
2000					
2500					
3150					
4000					
5000					
6300					
8000					
10000					
12500					

16000					
20000					
25000					
31500					
40000					
50000					
13 Remarks: the measurement organization is to provide complete and effective original time domain record data to CCS.					

Annex 1: Certificate of Calibration of Measurement Equipment

Annex 2: Detailed information on calculation of transmission loss (if applicable)

Annex 3: Figure of sound pressure spectrum source level of underwater radiated noise of ships with one-third octave band frequency band

Annex 4: Main radiated noise control measures

Annex 5: Propeller condition

Appendix 2 Revised Guidelines for the Reduction of Underwater Radiated Noise from Shipping to Address Adverse Impacts on Marine Life

1 PREAMBLE

1.1 Commercial shipping is one of the main contributors to underwater radiated noise (URN), which has adverse effects on critical life functions for a wide range of marine life, including marine mammals, fish and invertebrate species, upon which many coastal Indigenous communities depend for their food, livelihoods and cultures.

1.2 The effective mitigation of URN impact from ships on marine life requires international collaboration and action at various levels, involving multiple stakeholders including, but not limited to, seafarers, designers, shipbuilders, shipowners and ship operators, maritime authorities, suppliers, manufacturers and classification societies. Member States also play an important role in setting expectations for noise reduction targets and establishing mechanisms and programmes through which noise reduction efforts may be realized.

1.3 Sound is the primary sensory mechanism used by aquatic fauna for social interactions, reproduction, navigation, and detection of obstacles, prey, predators and other threats. The most relevant noise sources from ships overlap with hearing ranges and the use of sound by different species. Depending on the species, documented impacts on marine mammals, fish and invertebrates from URN include developmental impairment, poor body condition, increased predation, decreased offspring survival, less feeding, DNA fragmentation, behavioural changes, masking issues and physiological responses. Although impacts of shipping noise have been assessed considering the environment-related characteristics of different regions and the noise sensitivity of different species, based on field observations, laboratory experiments, modelling approaches and Indigenous Knowledge, further data on noise impact on ecologically and commercially key species will help inform stakeholders.

1.4 It is important to recognize that for both new and existing ships, the technical feasibility and cost-effectiveness of URN reduction measures, considered either individually or in combination, will be strongly dependent on the design, operational parameters and requirements relevant to a particular ship. A successful strategy to reduce URN should be a process that includes, to the extent possible, the design stage, the baselining of URN measurements (predicted or actual), the development of URN targets, and the implementation, monitoring and assessment of technical and operational measures to achieve those targets. The interactions between the implementation of URN reduction measures and other objectives such as, but not limited to, energy efficiency, biofouling reduction and ship safety, and the resulting contributions should be carefully considered.

2 APPLICATION

2.1 These Guidelines may be applied to any ship, taking into account their design and construction, and modifications, as well as their operation.

2.2 These Guidelines do not address the introduction of noise from warships and naval auxiliaries and the deliberate introduction of noise for other purposes such as sonar or seismic activities.

3 PURPOSE

3.1 The purpose of these Guidelines is to:

.1 provide an overview of approaches applicable to designers, shipbuilders and ship operators to reduce the URN of any given ship; and

.2 assist relevant stakeholders in establishing mechanisms and programmes through which noise reduction efforts can be realized.

3.2 Given the complexities associated with ship design and construction, and the various approaches for reducing and mitigating URN from ships, these Guidelines focus on identifying primary contributors to URN generated by ships and a general approach that designers, shipbuilders, shipowners and ship operators can undertake. URN prime contributors are associated with propellers, hull form, onboard machinery, wake flow, as well as operational and maintenance aspects.

3.3 These Guidelines describe URN reduction management planning as a tool that may be applied to the operation, design, construction and modification of ships, as far as is reasonable and practical.

3.4 In addition, ship and equipment designers, shipbuilders and shipowners and operators, maritime authorities, classification societies, suppliers, manufacturers and other stakeholders are encouraged to introduce and apply these Guidelines to their specific activities and consider any other technologies and operational measures not included in these Guidelines which may be more appropriate for specific applications and have demonstrated their effectiveness to further reduce URN.

3.5 The development of technological solutions to reduce URN and the scientific knowledge around the impact of URN on marine life will continue to evolve. These Guidelines will be reviewed and updated on a regular basis to ensure that relevant parties have the best available information to inform URN reduction efforts and to take account of linkages with energy efficiency compliance measures. Member States and Observers are encouraged to pass on experience and information received from ship and equipment designers, shipbuilders and operators, scientific organizations, civil society, Indigenous Knowledge holders and others, to assist in improving and updating these Guidelines.

4 DEFINITIONS

For the purposes of these Guidelines, the following definitions apply:

Baseline URN: the ship's source level (and associated source depth), for typical operational conditions, that follows from initial predictions and trials or preferably standardized measurements.

Cavitation: the reduction of the ambient pressure by a static or dynamic means that can be caused by the propeller or other devices, causing the formation of bubbles in the liquid. The formation refers to both the creation of a new cavity or the expansion of a pre-existing one. When these bubbles are travelling to regions of higher ambient pressure, they collapse generating the major source of noise from propelled ships.

Cavitation inception speed: the ship speed at which cavitation becomes detectable (either visually or acoustically).

Existing ship: a ship which is not a new ship.

Hearing range: the range of frequencies the ear or any other sensory organ of an animal can detect.

Indigenous Knowledge: a systematic way of thinking applied to phenomena across biological, physical, cultural and spiritual systems. It includes insights based on evidence and acquired through direct and long-term experiences and extensive and multigenerational observation, lessons and skills. It has developed over millennia and is still developing in a living process, including knowledge acquired today and in the future, and it is passed on from generation to generation. Under this definition, Indigenous Knowledge goes beyond observations and ecological knowledge, offering a unique "way of knowing".

Masking: where noise interferes with the detection and perception of other sounds important to marine fauna. Masking may, among other effects, cause a reduction or loss of communication range for marine species.

New ship: a ship for which the building contract is placed, or in the absence of a building contract, the keel of which is laid, or which is at a similar stage of construction, on or after the effective date of these Guidelines.

Propeller noise: caused by flow phenomena on the propeller as it operates in the wake field of the ship hull. Propeller noise is composed of non-cavitating propeller noise and cavitation noise. Once cavitation occurs, it is typically the most dominant noise source.

Radiated Noise Level (RNL): expressed as a sound pressure level in decibels. RNL is a ship source level that assumes the ship can be treated as an acoustic point source. It is computed by taking the product of the distance from a ship reference point, D, and the far-field root-mean-square sound pressure, PRMS(D), at that distance for a specified reference value. Mathematically,

$$RNL = 20 \cdot \log_{10}\left(\frac{P_{RMS}}{P_{REF}}\right) + 20 \cdot \log_{10}\left(\frac{D}{D_{REF}}\right) \quad dB$$

The reference value for pressure (P_{REF}) is 1 micro-Pa. The reference value for distance (D_{REF}) is 1 metre. A full technical definition is provided in ISO 17208-1:2016 (Underwater acoustics — Quantities and procedures for description and measurement of underwater sound from ships — Part 1: Requirements for precision measurements in deep water used for comparison purposes.

Sound Pressure Level: For underwater noise, 10 times the base-ten logarithm of the square of the ratio of the underwater root-mean-square sound pressure (*P*) divided by the reference sound pressure of 1 micro-Pascal, $SPL = 10 \cdot \log_{10}\left(P/P_{REF}\right)^2$, where P_{REF} = 1 micro-Pascal.

Structure-borne noise: Structure-borne noise is vibration in the structure of the ship which will generate noise when a vibrating surface excites the surrounding medium, i.e foundation, pipes, other coupled machines or linked auxiliary equipment. Structure-borne noise is usually measured and quantified using vibration metrics.

Source Level: for underwater source levels see ISO 18405:2017 (Underwater acoustics – Terminology). In general, the Source Level is used to quantify how much sound (or vibration) is generated by a device (machinery or other entity, such as a ship) at a reference distance (conventionally at 1 m for underwater acoustics).

Underwater radiated noise (URN) level: for the purposes of these Guidelines, refers to noise from any ship. URN level is to be reported in decibels as a sound pressure level.

Vibration isolation mounts: vibro-elastic elements (steel springs, rubber or other systems) used to isolate machinery vibration from the ship's structure by reducing the amplitude of vibrational energy. Vibration isolation mounts may also be used to protect the equipment from harmful vibration from outside the ship (e.g. shock inputs during rough weather).

5 UNDERWATER RADIATED NOISE (URN) MANAGEMENT PLANNING

5.1 URN Management Planning is a generalized approach applicable to ships in accordance with section 2 that includes possible strategies for URN reduction in design, construction, operation and/or modification.

5.2 Given the complexities associated with ship design and construction and the various approaches to reducing URN, shipowners and designers should undertake URN Management Planning at the earliest design stages. Similarly, URN Management Planning may be carried out for existing ships as far as is reasonable and practicable.

5.3 URN Management Planning is intended to be a flexible tool that allows a customized approach, and may include establishing the baseline (predicted or actual) of a ship's URN, setting URN targets which should be specific and, where possible, quantitative, and evaluating, alone and in combination, various technological, operational and maintenance approaches to reduce URN. Two model templates, with varying levels of detail, are provided in appendix C to help guide shipowners/designers in this process.

5.4 Various parties have the following opportunities to support an effective URN Management Planning, including but not limited to:

.1 Shipowners: develop and implement URN Management Plan, include URN requirements in ship design specifications and maintain ships to those specifications.

.2 Designers: design ships as defined by shipowners' operational plan to meet URN requirements.

.3 Shipbuilders: build ship to meet URN specifications.

.4 Ship operators: operate ship to meet URN targets and any additional regional requirements they are operating in.

.5 Maritime authorities: take supportive actions that enable and advance URN Management Planning, for example, supporting deployment of tools to measure ship noise levels, support innovation and adoption of noise reduction technologies, and communicate URN information.

.6 Classification societies: assist shipowners/builders through predictions, trials, relevant URN notations, certification, etc., as reasonable and practicable.

.7 Suppliers and manufacturers: provide equipment to shipbuilders and shipowners, which will assist the ship to meet URN specifications.

6 URN REDUCTION APPROACHES

6.1 The primary sources of URN generated by ships are associated with propellers, hull form, onboard machinery, wake flow as well as operational and maintenance aspects. At typical operating speeds, or near the design ship speed, most URN is caused by propeller cavitation, but onboard machinery and operational aspects are also relevant, especially below cavitation inception speed. Propeller noise itself can be a dominant contributor to overall URN. The optimal URN mitigation strategy for any ship should at least consider all relevant noise sources and mitigation strategies, including any that are not covered in these Guidelines, which may be more appropriate for specific applications.

Design and technical noise reduction approaches

6.2 The greatest opportunities for reduction of URN will be during the initial design and build stages of the ship. For existing ships, it is unlikely to be practical to match the URN performance achievable by new designs, with the exception of possible modification of propellers in some cases. The following design considerations are therefore primarily intended for consideration for new ships. However, consideration may be given to the modification of existing ships when reasonable and practicable. Table 1 summarizes the design and technical noise reduction approaches that are applicable to new and/or existing ships.

Hull design and modification

6.3 Flow around the hull may have an influence on URN, since the hull form influences the inflow of water to the propeller. Uneven or non-homogeneous wake fields are known to increase propeller cavitation. Therefore, the ship hull form with its appendages should be designed such that the wake field is as homogeneous as possible to reduce cavitation. Furthermore, the excitation of the ship structure induced by the propeller should not be neglected.

6.4 Consideration should be given to structure-borne noise, to reduce hull URN. Some mitigation measures could be optimization of scantling, application of a decoupling coating, and structural damping.

Propeller design and modification

6.5 Propellers should be designed and selected to minimize cavitation while considering and optimizing effects on energy efficiency. Cavitation can be the dominant URN source and may increase underwater radiated noise significantly. At typical operating speeds, cavitation can be reduced under normal operating conditions through good design, such as optimizing propeller load, ensuring uniform water flow through propellers (influenced by hull design), and careful selection of the propeller characteristics such as diameter, blade number, blade area, pitch, skew, rake and sections. Analyses and study of hull-propeller interaction can optimize the design of the propeller, hull, rudder and ship performance concurrently.

6.6 Noise-reducing propeller design options are available for many applications and should be considered. However, it is acknowledged that the optimal propeller with regard to URN reduction cannot always be employed due to technical or geometrical constraints (e.g. ice-strengthening of the propeller, mass). It is also acknowledged that some design principles for cavitation reduction can cause decrease of efficiency. Some new state-of-the-art propeller design and concepts have been developed, including high skewed propellers, forward-skew propellers and contra-rotating propellers.

6.7 Some emerging technologies are available to reduce required propulsion power, like wind-assisted-propulsion or hull-lubrication by means of air injection. Those technologies can be considered for possibly reducing the propeller loading and cavitation noise. Consideration should be given to the fact that propulsion load reduction does not have adverse effects on URN, for instance by producing cavitation on the suction side at the same power load level. Air bubble injection into the stern and propeller is also used for reducing URN.

Wake flow improvement

6.8 Improving hydrodynamic performance by optimizing hull form design, hull and propeller appendages (e.g. by adoption of a propulsion improving device/energy saving device or an asymmetric stern design) can increase performance and fluid inflow to propeller and reduce URN.

6.9 In order to improve the inflow of a ship propeller, there are many devices that could be used, but these may cause cavitation and as such, should be carefully designed either for new ships or existing ships. Cavitation performance of such devices could be evaluated, and model tested in a cavitation test facility along with the propeller cavitation test. These devices include:

.1 Installation of wake conditioning devices and optimization of the rudder design.

.2 Pre-Swirl Stator (PSS): some stators before the propeller that can decrease the Blade Passing Frequency (BPF) noise and increase the propeller efficiency.

.3 Pre-Shrouded Vanes: Vane and some stators before the propeller that can improve the cavitation performance of the propeller and increase the propeller efficiency.

.4 A hub cap with fins may be useful to improve the wake of a ship propeller. It can recover energy from the propeller wake and increase the propeller efficiency. A hub cap with fins can also help to avoid hub vortex cavitation.

Machinery design and modification

6.10 Consideration should be given to the selection of propulsion system and onboard machinery along with appropriate structure-borne sound control measures, proper location of equipment in the hull, and optimization of foundation structures that may contribute to reducing underwater radiated and onboard noise affecting passengers and crew. The ship machinery/equipment line-up should be optimized when or where there is a need to have a reduced noise profile. Reduced URN can be achieved by securing equipment that may not be needed at all times or even during certain parts of a transit. In addition, depending on the ship propulsion plant configuration, further URN reduction can be achieved through selective operation of engines and generator sets. For example, inboard mounted engines may produce lower URN than outboard mounted engines. A "quiet ship profile" can be developed by the measurement of URN of various equipment to understand each unit's contribution to the overall ship noise.

6.11 Airborne sound can excite structure-borne noise that is transmitted into the water. Designers, shipowners and shipbuilders should request that engine/machinery manufacturers supply information on the airborne sound levels and vibration produced by their machinery to allow analysis by methods described in appendix B and recommend methods of installation that may help reduce URN.

6.12 Consideration should be given for the appropriate use of vibration isolation mounts, as well as improved dynamic balancing for reciprocating and rotating machinery such as refrigeration plants, air compressors, and pumps. Vibration isolation of other items of equipment such as hydraulics, electrical pumps, piping, large fans, vent and air conditioning ducting may be beneficial for some applications, particularly as a mitigating measure where more direct techniques are not appropriate for the specific application under consideration. Active noise control can also be considered to dampen structure-borne vibration from these sources.

6.13 Vibration isolation mounts can reduce the vibration from machinery to the supporting structure and reduce the structure-borne noise. Because of the propulsion and thrust transfer arrangement, resilient mounts for engines can be mostly considered for four-stroke engines with geared drive, and not the two-stroke engine with direct drive. Two-stroke engines cannot use resilient mounting as the propeller thrust is transferred by the engine directly to the ship structure by the large engine seating area. Flexible coupling between the engine and gearbox can reduce vibration in a geared drive, and further reduce the structure-borne noise. Vibration isolators are more readily used for mounting diesel generators to their foundation for reducing structure-borne noise. In some cases, the adoption of a diesel-electric system should be considered, as it may facilitate effective vibration isolation of the diesel generators, which is not usually possible with large direct drive configurations.

6.14 Alternative power and propulsion systems can help reduce URN. Electric propulsion (e.g. diesel-electric, fuel cell and full electric or battery, podded propulsions or azimuth thrusters) is identified as a promising configuration option for reducing underwater noise. The use of high-quality electric motors and installations will also likely help to reduce vibration being induced into the hull from the electric motor.

Maintenance and operational approaches

6.15 Although the main components of URN are generated from the ship design (i.e. hull form, propeller, the interaction of the hull and propeller, and machinery configuration), operational adjustments and maintenance measures should be considered as ways of reducing noise for both new and existing ships. Operational approaches could be particularly important for ships that lack design features or technologies to reduce noise, or for all ships that operate in national and international designated protected areas where additional measures need to be taken to decrease the adverse impacts of shipping noise on marine wildlife. Table 1 summarizes the operational and maintenance approaches that are applicable to new and/or existing ships.

Maintenance approaches

6.16 Maintaining the surface quality/finish of propellers, such as when polishing is done properly, removes marine biofouling and vastly reduces surface roughness, helping to reduce propeller cavitation.

6.17 Reducing hull roughness and maintaining a smooth underwater hull surface, by utilizing proper coatings, cleaning, and proactive in-water hull maintenance,[1] may also improve a ship's energy efficiency by reducing the ship's resistance and propeller load. However, it should be noted that ultrasonic anti-fouling systems emit high-frequency sound energy in frequency ranges and at amplitudes that can be harmful to aquatic species. The use of such systems should be avoided where possible in national and international designated protected areas.

6.18 Machinery vibrations induce structure-borne noise. Proper maintenance of the moving parts and machinery, as well as vibration isolation mounts, helps to keep the vibration and noise low and prevent increasing the noise from operating that machinery.

Operational approaches

6.19 Optimizing the ship's trim and draught can reduce the required power and therefore propeller cavitation noise.

6.20 Operators can adjust and optimize ship's routeing, speed and sail time to reduce time at anchor and the URN in port and coastal areas. Voyage planning can facilitate the use of alternate routes to avoid protected areas and slowdown, when it can be safely done, in national and

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[1] Swain, G., Erdogan, C., Foy, L., Gardner, H., Harper, M., Hearin, J., Hunsucker, K.Z., Hunsucker, J.T., Lieberman, K., Nanney, M. and Ralston, E., 2022. *Proactive In-Water Ship Hull Grooming as a Method to Reduce the Environmental Footprint of Ships*. Frontiers in Marine Science, p.2017.

international designated protected areas and during critical times of year to decrease impacts of URN on marine life and communities which depend on them. Hydrographic offices and maritime administrations should consider marking and updating national and international designated protected areas in charts to enable the seafarers and harbour users to plan voyages to minimize the impact of their ship's URN on marine life.

6.21 Best practices include reviewing information on national and international designated protected areas to determine whether ships transit through or have operations in such areas. These may include but are not limited to sea-ice covered regions, including Inuit Nunaat, busy ports and shipping lanes overlapping with important or critical habitat for endangered, threatened, or protected species, Important Marine Mammal Areas, Marine Protected Areas as characterized by the Convention on Biological Diversity and other national/regional area-based protection.

6.22 In Inuit Nunaat, a number of characteristics of the region and the activities within them could increase the impacts from URN. This includes potential for icebreaking activities, presence of noise-sensitive species, and potential interference with Indigenous hunting rights. Additional efforts to decrease impacts on marine wildlife are advisable for ships that operate in these areas, including particular attention to reducing the noise impact from icebreaking and implementation of operational approaches and monitoring.

Ship speed

6.23 In general, for ships equipped with fixed pitch propellers, reducing ship speed, shaft RPM and/or engine output can be a very effective operational measure for reducing underwater noise, mainly due to reduced cavitation. This is especially the case when speeds are slower than the cavitation inception speed, but even small reductions in power can greatly reduce cavitation. Thus, overridable shaft power limitation or overridable engine power limitation (such as may be adopted to meet the IMO EEXI requirements) would be expected to reduce URN in situations where these limits are below the ship's usual operating power.

6.24 It is recommended to measure and understand the ship's Cavitation Inception Speed (CIS) and then operate below CIS in national and international designated protected areas when practicable. For ships equipped with controllable pitch propellers, there may be no reduction in noise with reduced speed. Therefore, consideration should be given to optimum combinations of shaft speed and propeller pitch.

6.25 However, there may be other, overriding reasons for a particular speed to be maintained, such as safety, operation and energy efficiency. Consideration should be given in general to any critical speeds of an individual ship with respect to cavitation and resulting increases in URN.

Table 1 Summary of design, technical, operational and maintenance URN reduction approaches applicable to new and/or existing ships as far as practicable. This list is not exhaustive and should not restrict any other design options that a shipowner may consider as a solution. Please see Ship underwater radiated noise technical report and matrix for further information.

URN Reduction Approaches	New ship	Existing ship
Optimize ship hull form (and appendages) design for hydrodynamic performance and homogeneous wake field to reduce cavitation	X	X
Optimizing propeller design to reduce cavitation, optimizing load, ensuring a	X	X

uniform water flow and hull-propeller interaction and careful selection of the propeller characteristics such as diameter, blade number, blade area, pitch, skew, rake, and sections and innovation material		
Emerging technologies like wind-assist technologies to reduce propeller loading and cavitation noise	**X**	**X**
Air injection to propeller	**X**	**X**
Wake flow improvement	**X**	**X**
Careful selection of onboard machinery and installation with appropriate structure-borne noise levels control measures, proper location of equipment in the hull, and optimization of foundation structures	**X**	
Machinery installation and isolation for instance resilient mount and flexible coupling in four-stroke engines with a reduction gear, vibration isolation mounts and improved dynamic balancing for reciprocating machinery	**X**	**X**
Optimizing the ship's trim to reduce the required power and therefore propeller cavitation noise	**X**	**X**
Improving voyage planning (e.g. optimum route, coordinated across fleets, national and international designated protected areas/sea-ice covered region, including well-known habitats or migratory pathways)	**X**	**X**
Decreasing propellor RPM by reducing the shaft RPM (and/or engine output) for ships equipped with fixed pitch propellers[2]	**X**	**X**
Ships routeing measures[3] to avoid national and international designated protected areas including well-known habitats or migratory pathways	**X**	**X**
Propeller maintenance (and cleaning/coating)	**X**	**X**
Hull maintenance (coating and in-water hull maintenance and cleaning, except acoustic anti-fouling systems where possible in national and international designated protected areas)	**X**	**X**

7 ENERGY EFFICIENCY AND URN REDUCTION

7.1 Careful consideration should be given to the interrelationships between energy efficiency, GHG and URN reduction while adhering to regulatory obligations and ensuring that the level of URN will meet set targets as established in the URN Management Plan. Many of the energy efficiency improvement options to meet energy efficiency regulations (EEDI, EEXI and CII) may result in an improvement in URN performance and could provide positive synergies with climate policies. Where URN reduction measures are not supportive of energy efficiency, then regulatory obligations pertaining to energy efficiency and emissions must take precedence. URN measures should not come at the expense of IMO requirements on GHG reduction and energy efficiency or

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[2] It is vital that sufficient speed and power for safe navigation is maintained. Please refer to MEPC.1/Circ.850/Rev.3 on G*uidelines for determining minimum propulsion power to maintain the manoeuvrability of ships in adverse conditions*.

[3] "Ship routeing measures" refers to the process of moving existing recognized shipping lanes away from national or international protected areas, which may include important marine mammal habitat or migratory pathways. Ship routeing is known as an effective measure to reduce ship noise exposure in the marine environment.

other IMO requirements affecting the ship safety as for example manoeuvrability.

7.2 Designers, builders, shipowners and operators should investigate and consider the risk of increasing URN with ship design to achieve lower EEDI, EEXI and/or CII.

7.3 Scrutiny should be given to the co-design of hull and propeller as a unit, such that a uniform wake flow is created to reduce propeller cavitation, as this will also increase energy efficiency, and reduce emissions.

7.4 Reducing propeller cavitation is an effective means of reducing URN. Measures aimed at reducing applied or installed propulsion power and propeller thrust loading, with the appropriate safety caveats,[4] are options to improve energy efficiency, reduce emissions, and typically result in URN reduction, e.g. wind assistance, optimized hull design, and regular maintenance and hull cleaning to avoid fouling and reduce hull resistance are all effective measures for reduced emissions and URN.

7.5 URN computational methods should integrate optimization methods to include the parameters affecting energy efficiency and other emissions at the same time as underwater noise. This will allow optimization with respect to URN, other emissions and efficiency/performance.

8 EVALUATION AND MONITORING

8.1 Evaluation and ongoing monitoring of URN is an essential step towards assessing the effectiveness of efforts to reduce noise in the oceans. This may be done through actual measurement of ship URN, or through the modelling of ship URN based on its characteristics and design parameters, as well as environmental conditions.

8.2 Modelling of URN needs to take into account sound propagation loss as this is influenced by several environmental parameters (e.g. sea state, sea ice, sound speed profile, seawater temperature, sound absorption, currents, bathymetry, the properties of the sea bottom). There exist a variety of underwater sound propagation models to address the objectives of the specific application.

8.3 Efforts should be made to better understand status and changes in URN. Monitoring capacity developed in partnership with interested ports should be encouraged along shipping lanes and used in incentive programmes to complement other URN monitoring programmes, where possible.

8.4 Efforts should be made to support community-led efforts to understand underwater noise from shipping and its impacts on marine species and coastal communities.

8.5 Member States and other stakeholders, including classification societies, designers, shipbuilders, shipowners and ship operators, suppliers and manufacturers may contribute data, where possible, to the global understanding of ship noise emissions, including through established monitoring programmes of ship source levels and/or ambient noise.

8.6 URN data gathered, and results of applied measures may be shared by submitting information, observations, suggestions, comments and recommendations based on the practical experience gained through the application of these Guidelines to the Marine Environment Committee under "Any other business". Data can be shared anonymously for the purpose of supporting planning and development of URN measures by the Member States, and other stakeholders.

9 INCENTIVIZATION

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[4] See MEPC.1/Circ.850/Rev.3.

9.1 Maritime authorities, financial and insurance institutions and others are encouraged to promote establishing incentive schemes to support the implementation of URN monitoring programmes and noise reduction efforts by suppliers, designers, shipbuilders, shipowners and operators, where considered appropriate. Incentives can also support the collection and sharing of data about ship URN generally.

9.2 Incentivization could be, for instance, based on relevant URN ship class notations, recognition of a URN Management Plan, URN reduction targets, ship and engine technologies and maintenance, ship speed reduction programmes, Onshore Power Supply in-port or other voluntary sustainability certifications which include evidence of URN reduction or complementary benefits on efficiency and maintenance (e.g. preventing biofouling by in-water cleaning of ship hull and propeller could increase efficiency and minimize the transfer of invasive species).

9.3 Examples of incentives are discount on the port dues, fairway fees, or extra services or products, promotion, among others.

9.4 Suppliers, designers, builders, shipowners and operators should make themselves aware of and strive to achieve incentives related to URN reduction.

APPENDIX A INTERNATIONAL URN MEASUREMENT STANDARDS, RECOMMENDATIONS AND CLASSIFICATION SOCIETY RULES

1 Shipowners, designers and operators and other stakeholders may use the most appropriate and updated noise measurement standard listed below for their context.

2 ANSI S12.64 and ISO-17208-1 [5] are two versions of the same standard. It included three grades: survey, engineering and precision, with the latter being the most accurate methodology. ISO-17208-1 was taken from S12.64 and adopted for international use, with the primary difference being the removal of the three grades. Both standards are for the measurement of the Radiated Noise Level (RNL) of a ship in deep water. ISO-17208-2 [6] provides a methodology to take data measured using ISO-17208-1 and convert the measured RNL to Monopole Source Level (MSL). These two standards would be most relevant to the measurement of ship noise. Both standards would be necessary, when using MSL metrics.

Non-exhaustive List of URN Measurement Standards

Standard or Organization	Date issued	Scope	Methodology	Minimum water depth
ICES-CRR-209[7]	May 1995	Applies only to fishery research vessels (R/V). This document provides guidance on ambient noise, fish hearing, ship noise, fish reaction to ship noise, URN instrumentation, noise mitigation for R/Vs.	The intended methodology results in sound pressure level at 1 metre in 1 Hertz (narrowband) spectrum. No distance correction process is given.	Not specified
ANSI/ASA S12.64[8]	Sep 2009	Applies to any ship of any size with speed less than 50 knots. (This is the first standard for URN measurement of commercial ships.)	Results are in sound pressure level at 1 m assuming the ship is modelled as a point source using spherical spreading. There are three grades of	*Prec.*: 300 m or 3x L *Eng*: 150 m or 1.5x L *Survey*: 75 m or 1x L

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[5] ISO 17208-1 Underwater acoustics — Quantities and procedures for description and measurement of underwater sound from ships — Part 1: Requirements for precision measurements in deep water used for comparison purposes.

[6] ISO 17208-2 Underwater acoustics — Quantities and procedures for description and measurement of underwater sound from ships — Part 2: Determination of source levels from deep-water measurements.

[7] International Council for the Exploration of the Seas (ICES), Cooperative Research Report 209, *Underwater Noise of Research Vessels, Review and Recommendations*, dated May 1995.

[8] American National Standards Institute (ANSI)/Acoustical Society of America (ASA) S12.64-2009; *Quantities and Procedures for Description and Measurement of Underwater Sound from Ships – Part 1: General Requirements*, dated September 2009.

			measurement: Precision, Engineering, and Survey. Uses three hydrophones located in the water column with a beam aspect.	where L is overall ship length.
Bureau Veritas, DNV[9]	Nov 2015	Applies to commercial ships, which includes any ship engaged in commercial trade or carrying passengers for hire.	Results are in sound pressure level at 1 m using calculated propagation loss with the ship modelled as a monopole sound source.	Not specified
ISO-17208-1[10]	March 2016	Same as S12.64 (above)	Methodology and results are mostly the same as S12.64 but with a single grade between the precision and engineering grades of S12.64. Uses three hydrophones located in the water column with a beam aspect	Greater of 150 m or as given in Note (1)
ITTC Guidelines 7.5- 04[11]	Sep 2017	Applies to measuring underwater radiated noise from surface ships.	Results are in sound pressure level at 1 m assuming spherical spreading and adjusted by a distance normalization.	300 m or three times ship length for highest grade; 150 m or 1.5 times ship length for middle grade; 75 m or 1 times ship length for lowest grade.

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[9] Achieve Quieter Oceans by Shipping Noise Footprint Reduction (AQUO) and Suppression of UW Noise Induced by Cavitation (SONIC), *Guidelines for Regulation on UW Noise from Commercial Shipping*.

[10] International Standards Organization (ISO), ISO-17208-1-2016; *Underwater acoustics — Quantities and procedures for description and measurement of underwater sound from ships — Part 1: Requirements for precision measurements in deep water used for comparison purposes*, dated March 2016.

[11] International Towing Tank Conference (ITTC), Recommended Procedures and guidelines - Underwater Noise from Ships - Full scale measurements.

Lloyds Register[12]	Feb 2018	Applies to any ship which had URN measured and certified in accordance with LR's *SHIPRIGHT* notation.	Deep-water correction provided assuming measurements in accordance with ISO-17208-1. Shallow water shall be performed as given in ISO-17208-1. Uses three hydrophones located in the water column with a beam aspect.	Greater of 60 m or as given in Note (2)
Bureau Veritas[13]	July 2018	Applies to any self-propelled ship.	Results are in sound pressure level at 1 m using calculated transmission loss with the ship modelled at a monopole sound source. Uses three hydrophones located in the water column with a beam aspect.	Greater of 60 m or as given in Note (3)
China Classification Society[14]	Oct 2018	Applies to ships applying for CCS class notation.	Results are in sound pressure level at 1 m assuming spherical spreading and using calculated transmission loss.	When the single hydrophone method is used, the keel clearance is in general not to be less than 40 m and not less than 60 m for a multiplehydrophone method.
ISO-17208-2[15]	July 2019	This document specifies methods for calculating an equivalent monopole source level by converting radiated noise level values obtained in deep water according to ISO	This is not a ship measurement standard, must use ISO-17208-1 for field measurements.	N/A

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[12] Lloyd's Register (LR), *Additional Design Procedures, Additional Design & Construction Procedure for the Determination of a Vessels Underwater Radiated Noise*, February 2018.

[13] Bureau Veritas, *Underwater Radiated Noise*, Rule Note NR 614 DT R02 E, dated July 2018.

[14] China Classification Society, *Guidelines for underwater radiated noise of ships*, October 2018.

[15] International Standards Organization (ISO), ISO-17208-2-2019; *Underwater acoustics — Quantities and procedures for description and measurement of underwater sound from ships — Part 2: Determination of source levels from deep water measurements* dated July 2019.

		17208-1.		
DNV[16]	July 2019	Applies to all ships looking to achieve the DNV-GL *SILENT* notation.	Deep-water methodology to follow ISO-17208-1 (given above). Shallow water uses unique method with a single bottom mounted hydrophone and distance correction performed using actual site measured transmission loss or the relationship 18xLog(r) where r is the distance between the ship and hydrophone.	150 m (for deepwater testing regardless of ship length) 30 m (for shallow water testing)
DNV[17]	July 2020	Applies to all ships looking to achieve the DNV-GL *SILENT* notation.	Results are in sound pressure level at 1 m assuming the ship is modelled as a point or line source as determined during the evaluation. This document only provides the limits and need to conduct measurement according to DNVGL-CG-0313 (above).	N/A
ABS[18]	May 2021	Applies to self-propelled commercial and research ships	Results are in sound pressure level at 1 m using spherical spreading for deep water and calculated transmission loss (by provided equation) for shallow water. Uses three hydrophones located in the water column with a beam aspect.	Greater of 60 m or as given in Note (4)

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[16] Det Norske Veritas/Germanischer Lloyd (DNV/GL), Class Guideline DNVGL-CG-0313, *Measurement procedures for noise emission*, dated July 2019.

[17] Det Norske Veritas/Germanischer Lloyd (DNV/GL), Rules for Classification, Ships, Part 6, *Additional class notations, Chapter 7 Environmental Protection and Pollution Control*, dated July 2020.

[18] American Bureau of Shipping (ABS), *Underwater Noise and External Airborne Noise*, dated May 2021.

RINA[19]	2021	Applies to all ships looking to achieve the RINA *DOLPHIN QUIET* or *TRANSIT* notations.	Results are in sound pressure level at 1 m assuming the ship is modelled as a point source using spherical spreading. Uses three hydrophones located in the water column with a beam aspect.	150 m or as given in Note (5)
Korean Register[20]	July 2021	Applies to new and existing ships that have applied for the optional notation URN (Underwater Radiated Noise) for the ship's underwater radiated noise	Results are in sound pressure level at 1 m	At least 60 m

MINIMUM WATER DEPTH NOTES:

1. ISO-17208-1: 1.5 x overall ship length which is the longitudinal distance between the forward-most and aft-most part of a ship.
2. Lloyds Register: 0.3 x v^2 where v is ship speed in m/s or 3 x $(B \times Dt)^{1/2}$ where B is ship width and Dt is ship draught both in metres.
3. Bureau Veritas: 0.3 x v^2 where v is ship speed in m/s. Deep water is 200 m or 2x the ship length unless the ship is greater than 200 m then 1.5 times the ship length.
4. ABS: 0.3 x v^2 where v is ship speed in m/s. Deep water is the greater of 150 m or 1.5x the ship length.
5. RINA: Measurements can be performed in shallow water as long as adequate procedure for actual transmission loss has been agreed with RINA.

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[19] Registro Italiano Navale (RINA), Dolphin Quiet Ship and Dolphin Transit Ship, dated 2021.

[20] Korean Register: Guidance for Underwater Radiated Noise (July 2021).

APPENDIX B
TYPES OF COMPUTATIONAL MODELS FOR OPTIMIZING SHIP DESIGN AND TECHNICAL UNDERWATER RADIATED NOISE REDUCTION APPROACHES

Types of computational models for optimizing ship design and technical URN reduction approaches are:

.1 **Flow characteristics:** Computational Fluid Dynamics (CFD) can be used to predict and visualize flow characteristics, cavitation and hydroacoustic sources around the hull and appendages, and the wake field in which the propeller operates. Also, propeller analysis methods such as lifting surface methods or CFD can be used for predicting and trialling the effect of cavitation on the propeller performance.

.2 **Noise radiation:** Finite Element Analysis, Boundary Element Method and Statistical Energy Analysis can be used to estimate radiated noise due to flow field, cavitation, and machinery excitations. Bathymetry, sea bottom, sea surface and the elastic ship structures can be accounted for. Other methods to predict radiation include hybrid methods, wave-based methods, and Energy Flow Method. Most methods can be used both for structures and fluids.

.3 **Noise propagation:** the noise path from source to receptor, depends on the environment and some sound characteristics. Methods such as ray theory, normal modes, wavenumber integration or parabolic equations can be used for modelling long-range propagation of sound.

Standardized model tests of propeller URN in combination with cavitation tests provide the possibility for manufacturers, suppliers, shipowners and shipbuilders to agree whether contractual specifications regarding the propeller contribution to URN are fulfilled before the ship is built.

.1 Model-scale cavitation tests[21] have a possibility to offer at present the most accurate prediction and trial of URN source levels of cavitating propellers showing good to acceptable agreement with sea trials on URN source levels. However, scale effects and the effect of facility dependent background and reverberation noises should be considered carefully, and further improvements on these topics are expected from ongoing studies. Furthermore, as these model tests focus on cavitation noise only, the impact of a cavitation noise mitigation measure can be well evaluated. The impact of this mitigation measure on the total ship noise requires knowledge of the other noise sources such as machinery and structure-borne noise.

.2 The ship, its propeller, and special appendages (such as shaft bracket and Fin Stabilizer) could be model tested in a cavitation test facility such as a cavitation tunnel for measuring the design aspects with respect to cavitation induced pressure pulses, cavitation inception speed and radiated noise.

URN model predictions and trials should be assessed, when possible, with scaled or full-size model validation tests preferably in controlled environments.

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[21] ITTC – Recommended Procedures and Guidelines, Model-Scale Propeller Cavitation Noise Measurements, 7.5–02–03–03.9.

APPENDIX C
SAMPLE TEMPLATES FOR URN MANAGEMENT PLANNING

To assist shipowners with the development of a URN management plan that can be customized to meet their needs, two templates are provided as samples of what a URN management plan may contain. These are provided solely for guidance and can be further modified to address specific contexts of individual shipowners.

Sample Template #1: Aspirational plan with initial steps:

Underwater Radiated Noise Management Plan

1. Objective

This section should include an overview of the high-level objective regarding URN reduction of ships. For example, this may be framed as "Over the next five years, we intend to achieve the following objectives [….], and identify further opportunities to reduce the noise from our ships".

2. Approach

This section should describe the various efforts that will be taken to achieve the overall objective. This may include investments in research, efforts to measure the noise signature of ships, identification/implementation of operational or technical solutions relevant to the ship.

3. Monitoring/Evaluation Methods

This section should include a brief outline of how the shipowner/ship operator intends to monitor, assess and evaluate the progress of their plan over time.

Sample Template #2: Detailed plan that more explicitly follows the Plan-Implement-Monitor-Evaluate cycle

Underwater Radiated Noise Management Plan

1. Overview

This section should include an overview of the high-level objective regarding the URN reduction of ships and the intention of the plan. For example, this may be framed as "Over the next five years, we intend to achieve the following objectives [….], implement the following steps […] identify further opportunities to reduce the noise from our ships".

2. Baseline URN

This section should provide an overview of how a baseline URN could be determined.

As far as practicable, efforts should be made to determine a ship's baseline. Ship baseline URN condition may be predicted (computational/empirical/model tests) or preferably measured. Baselining the predicted and/or measured URN ship condition should be conducted under the ship's normal operating conditions, including typical operational speed and draught, with use of standard operating equipment/machinery.

URN should be measured to an objective standard. Appendix A summarizes the availability of recognized measurement standards that have been used in research and to support port programmes. Appendix B provides examples of computational models for optimizing ship design and technical noise reduction approaches.

3. URN targets

This section should outline the overall target source-noise reductions that the plan is aiming to achieve. The information below provides some possible guidance on how said targets could be established.

Research has documented significant variability among regions in underwater sound propagation conditions, contributions to URN levels and hearing sensitivity and adverse physiological or behavioural responses to ship noise among marine species. Biologically based noise limits are thus likely to reflect this variability, with any universal limit serving as a summary of impact reduction interests across diverse environments. However, individual ship-based noise targets established by ship class, tonnage or another characteristic can be established based on baseline measurements, actual or predicted. These URN reduction targets can be gradually strengthened over a specified period, to be established by the shipowner.

URN targets for a given ship should consider the ship's purpose, type, URN prediction and baseline measurement, as well as operational considerations. URN reduction targets can also be established by adoption of one of the classification societies' sets of URN-related rules. Alternatively, shipowners can establish URN reduction targets, inter alia, reducing noise levels by a certain percentage.

4. URN reduction approaches and related actions

This section provides the opportunity to clearly articulate the approaches to be taken to reduce underwater noise. This could include a combination of both technical and operational approaches, that may be adapted over time. It may also include the identification of research initiatives or other collaborative projects to advance knowledge and awareness of URN reduction efforts. See section 6 of the guidelines for guidance on the types of approaches that could be utilized.

5. Monitoring and evaluation

This section should show how ship noise reduction efforts could be monitored and evaluated.

As part of URN Management Planning, shipowners and operators should develop a monitoring approach to evaluate periodically the effectiveness of ship noise reduction efforts in comparison with baseline measurements and URN targets and to guide and enhance activities aimed at noise reduction (section 8). Such evaluation may include forms of URN measurements, simulations, modelling or other scientific methods of data gathering and evaluation.

Consideration should be given to measuring the ship's URN from the identified noise sources at expected range of typical operating conditions to determine if the URN targets of the ship are being met. These measurements should enable ship operators to optimize ship operation and adjust URN levels appropriately along a route (e.g. by optimization of the ship's trim, thereby reducing the required power, or by reducing speed, when safe to do so, both possibly resulting in reduced propeller cavitation noise). Verification of maintenance of previously acceptable noise levels may also be demonstrated by records of adequate maintenance of machinery, hull and propeller condition.

Between measurement activities, URN can be monitored in situ. Development of real-time dynamic voyage optimization tools which provide personalized analytical information to increase efficiency, save on fuel and costs, and reduce emissions show promise for adaptive management. Noise reduction should be added as a further optimization option.