

SUB-COMMITTEE ON SHIP DESIGN AND
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Agenda item 17

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**PROVISIONS FOR REDUCTION OF NOISE FROM COMMERCIAL SHIPPING
AND ITS ADVERSE IMPACTS ON MARINE LIFE**

Report of the Correspondence Group

Submitted by the United States

SUMMARY

Executive summary: This document provides the correspondence group's report regarding development of draft non-mandatory guidelines for reducing underwater noise from commercial ships.

Strategic direction: 7.1

High-level action: 7.1.2

Planned output: 7.1.2.3

Action to be taken: Paragraph 10

Related documents: MEPC 59/19; MEPC 60/18; MEPC 58/INF.19; MEPC 61/19, MEPC 61/19/1; MEPC 62/11/10, MEPC 62/INF.22; DE 56/2/1, DE 56/24 and DE 56/25

Introduction

1 The Sub-Committee, during its fifty-sixth session, established a correspondence group on minimizing underwater noise with the following terms of reference:

- .1 taking into account document DE 56/24 and the information contained in documents MEPC 59/19 and MEPC 60/18, giving special consideration to the priority focus areas identified in the two latter documents, continue to examine the available options for ship-quieting technologies and operational practices;
- .2 develop non-mandatory draft guidelines for reducing underwater noise from commercial ships; and
- .3 submit a report to DE 57.

2 The following Member States participated in the work of the correspondence group:

ARGENTINA	MARSHALL ISLANDS
AUSTRALIA	NETHERLANDS
CANADA	NORWAY
CHINA	REPUBLIC OF KOREA
FINLAND	SPAIN
GERMANY	SWEDEN
ITALY	TURKEY
JAPAN	UNITED KINGDOM
LIBERIA	UNITED STATES

and observers from the following non-governmental organizations and intergovernmental organizations:

INTERNATIONAL CHAMBER OF SHIPPING (ICS)
INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO)
BIMCO
FRIENDS OF THE EARTH INTERNATIONAL (FOEI)
INTERNATIONAL COUNCIL OF MARINE INDUSTRY ASSOCIATIONS (ICOMIA)
COMMUNITY OF EUROPEAN SHIPYARDS' ASSOCIATIONS (CESA)
WORLD WIDE FUND FOR NATURE (WWF)
INSTITUTE OF MARINE ENGINEERING, SCIENCE AND TECHNOLOGY
(IMarEST)
INTERNATIONAL MARINE CONTRACTORS ASSOCIATION (IMCA)
INTERNATIONAL FUND FOR ANIMAL WELFARE (IFAW)
WORLD SHIPPING COUNCIL (WSC)
CLEAN SHIPPING COALITION (CSC)
PACIFIC ENVIRONMENT
INTERNATIONAL WHALING COMMISSION (IWC)
EC (EMSA)

3 The United States appreciates the hard work and contributions by all the participants. A considerable amount of progress was made in the development of the draft guidelines.

Development of the draft guidelines

4 As stated in the terms of reference for the correspondence group, the draft guidelines are based on documents MEPC 59/18, MEPC 60/18, and DE 56/24. In an effort to facilitate this task, the Coordinator proposed using the draft framework in document DE 56/24 as the base working document. It was then circulated to the correspondence group for further review and comment. The updated version of the draft Guidelines for minimizing underwater noise from commercial ships is provided in the annex to this document.

5 The correspondence group agreed that the guidelines are intended to provide general advice to designers, shipbuilders, and owners about the primary sources of underwater noise from commercial ships which include propeller cavitation, hull form design, onboard machinery and operational measures.

6 It should be noted that the correspondence group could not reach agreement regarding the appropriate level of detail that should be incorporated into the technical recommendations within the guidelines. The majority of members felt that these guidelines should focus on providing general advice, rather than advocating specific solutions. Some

members noted that it is far too early to set up guidelines with prescriptive technical solutions without knowing their real effect on the environment and on the ship itself. It was suggested that an effective noise reduction strategy should refer specifically to the individual ship and operational scenario and should use a goal-based approach, which relies on a sound impact assessment.

7 The correspondence group agreed to reference the ANSI/ASA standard, currently the only existing underwater noise measurement standard, in the guidelines until ISO standards are completed. It is anticipated that the ISO standard for measurement of underwater radiated noise from merchant ships will be published in early 2013.

Items in the draft guidelines requiring further consideration

8 Square brackets have been used in the draft guidelines to indicate specific text or paragraphs that require further consideration. These items are discussed below (by paragraph number in the draft guidelines):

- .1 Preamble, paragraph 3: This item has been inserted for further discussion and consideration at DE 57;
- .2 paragraphs 3.1 through 3.7: Definitions have been proposed for terms used within the guidelines. This item should be further considered at DE 57;
- .3 paragraphs 4.2 and 4.3: The majority of the group was of the view that amplifying information regarding available computational models should be included in the guidelines. Several proposals have been included for further consideration at DE 57;
- .4 paragraph 6.1.1: There were mixed views on whether to include dB levels and/or frequency ranges in the guidelines. Some members expressed concern that the guidelines should not include specific numbers because noise parameters vary depending upon the design characteristics of the ship. Others preferred to note that an increase in noise level of [20dB] or [20dB in the 10Hz to 100,000Hz band]. This item should be further considered at DE 57;
- .5 paragraphs 6.1.1.1 and 6.1.1.2: Several members expressed concern that the bracketed text is too specific in nature and imply that these specific solutions will be applicable in all design cases, and they were of the opinion that this text should be deleted. These items should be further considered at DE 57;
- .6 paragraph 6.1.2: Several members expressed concern that the paragraph is too specific in nature and implies that these specific solutions will be applicable in all design cases, and they were of the opinion that this text should be deleted. This item should be further considered by at DE 57;
- .7 paragraph 6.2.1: The majority of the group was of a view that these paragraphs should be included within the guidelines. However, one member expressed concerns that hull design should not be included because turbulence around the hull has negligible influence on radiated noise and that considerable research is needed to quantitatively relate underwater radiated noise levels to design and operational parameters of the ship. This item should be further considered at DE 57;

- .8 paragraph 6.2.2: There were mixed views on whether structure optimization is an effective measure in control of noise and vibration. One member was of the view that for merchant ships the contribution of hull hydrodynamic noise is far less than the radiated noise from the structure excited by the mechanical equipment and propeller cavitation noise. The hull shape and surface factors will only affect the hydrodynamic noise, but the hull structure parameters can affect fluid-structure interaction noise. Others members were concerned that more research in this area is needed before this proposal can be incorporated into the guidelines. This item should be further considered at DE 57;
- .9 paragraph 7.2.3: There were mixed views on including this paragraph in the guidelines. Several members expressed concerns that these propulsion technologies are not commonly used on commercial ships and should not be included in these guidelines. Others expressed that inclusion of the paragraph highlights the use of other propulsion systems and gives more options for the designer, owner, and shipbuilder to consider. This item has been inserted for further discussion and considered at DE 57;
- .10 paragraph 7.4: The majority of the group was of the view that this paragraph should be included within the guidelines. However, some members were of the view that this paragraph should not be included because HVAC fans are only important for reduction of airborne noise in compartments. This item should be further considered at DE 57;
- .11 paragraph 7.5: There were mixed views on including sea pipe systems in the guidelines. Several members expressed concerns over including this paragraph because flow induced noise due to systems such as seawater cooling system is an unknown quantity and any relations between the two are questionable. This item should be further considered at DE 57;
- .12 paragraph 8.3: There were mixed views on including an inspection and maintenance provision. One member stated that this section should be deleted because the terms inspection and maintenance are not defined. This item should be further considered at DE 57;
- .13 paragraph 8.4: The majority of the group was of the view that the paragraph should be included. One member expressed concern that a ship's speed resulting in minimum noise may not be the optimum speed for fuel consumption and that additional research is needed in this area. This item should be further considered at DE 57; and
- .14 paragraphs 9.1 to 9.6: There were mixed views on including this section in the guidelines. Some members expressed the view that this section of the guidelines is repetitive and is covered elsewhere in the guidelines. Other members expressed concern that the effectiveness of noise reduction strategies will be ship specific, and it could be misleading for preliminary guidelines to imply support for a limited list of specific solutions that may not be generally applicable. This section has been inserted for further discussion and considered at DE 57.

Proposals considered to be beyond the terms of reference

9 The Sub-Committee is invited to note that the group considered the following proposals were determined to be related to higher level policy objectives that should be considered by MEPC and were beyond the terms of reference of this Correspondence Group:

- .1 Including a specific noise reduction target from the 2008 Hamburg International Workshop on Shipping Noise and Marine Mammals: to reduce the contribution of shipping to ambient noise levels in the 10-300Hz range of 3dB in 10 years and 10dB in 30 years, relative to current levels.
- .2 Evaluating the contribution of underwater noise from vessels and other sources (land based, drilling, ice breaking, etc.) so that mitigation can be directed at the largest contributor(s).
- .3 Quantification of the relationship between individual ship noise and regional ambient noise level reductions.
- .4 Continued progress in quantifying and understanding the adverse impact of noise on marine species;
- .5 Setting operating Guidelines for sensitive marine areas that have significant noise issues where specific operational and/or design measures may be needed to fundamentally reduce underwater noise from ships that operate there regularly, because of their impact on marine life.
- .6 Identifying the types of areas and situations when waterborne noise is most disruptive for marine life (near shore, during migration, ice breaking, etc.).
- .7 Using standardized measurement protocols to develop noise profiles for each ship type under different operating conditions.
- .8 Identifying the noisiest ships to gain a better understanding of the factors that elevate the noise levels of these ships.
- .9 Establishing baseline ambient noise levels in ocean areas of key concern such as those with high levels of marine biodiversity where shipping activities are forecasted to rapidly increase.
- .10 Collect and provide information on sensitive areas, including well-known habitats or migratory pathways, to ship masters and owners for the purpose of voyage planning.

Action requested of the Sub-Committee

10 The Sub-Committee is invited to:

- .1 consider the comments and proposals provided in this document and in the annex; and
- .2 consider establishing a working group at DE 57 to further refine the draft guidelines.

ANNEX

GUIDELINES FOR MINIMIZING UNDERWATER NOISE FROM COMMERCIAL SHIPS

Preamble

1 Concern has been raised that a significant portion of the underwater noise generated by human activity may be related to commercial shipping. The international community recognizes concern that underwater radiated noise from commercial ships may have both short- and long-term negative consequences on marine life, especially marine mammals.

2 It is important to recognize that both the technical and cost effectiveness of measures considered either individually or in combination will be strongly dependent on the design, operational parameters, and mandatory requirements relevant for a particular ship. A successful strategy to reduce radiated noise should consider interactions and contributions from measures provided to achieve other objectives such as reduction of onboard noise and improvements in energy efficiency.

[3 Noting the importance of evaluation of ship underwater noise radiated from commercial ships under various operating conditions, it is suggested that where practicable, evaluation is undertaken by the company to determine the success or otherwise of ship noise reduction efforts and to guide and enhance future efforts at noise reduction.]

1 Application

1.1 These guidelines can be applied to any commercial ship.

1.2 These guidelines do not address the introduction of noise from naval or war ships or the deliberate introduction of noise for other purposes such as sonar or seismic activities.

2 Purpose

2.1 These non-mandatory guidelines are intended to provide general advice about reduction of underwater noise to designers, shipbuilders and ship operators. They are not intended to form the basis of a mandatory document.

2.2 Given the complexities associated with ship design and construction, the guidelines focus on primary sources of underwater noise. These are associated with propeller design, hull form, onboard machinery, and operational aspects. Much, if not most, of the underwater noise is caused by propeller cavitation. Hull design, onboard machinery, and operational modification issues may also be relevant, but of secondary importance. The optimal underwater noise mitigation strategy for any ship should at least consider a combination of factors related to these areas.

2.3 These guidelines consider common technologies and measures that may be relevant for most sectors of the commercial shipping industry. Designers, shipbuilders, and ship operators are encouraged to also consider technologies and operational measures not included in these guidelines, which may be more appropriate for specific applications.

[3 Definitions

3.1 Underwater radiated noise for the purposes of these guidelines refers to man-made noise from commercial ship sources.

3.2 Propeller cavitation is the formation and implosion of water vapour cavities caused by the reduction and increase in pressure as water moves across a propeller blade. Cavitation causes broadband noise and discrete peaks in the underwater noise spectrum. The broadband noise is caused by growth and collapse of a vast amount of individual cavitation bubbles in water. The discrete noise peaks are caused by the volume fluctuations of the sheet and tip vortex cavities.

3.3 Cavitation inception speed is the lowest propeller speed at which cavitation occurs.

3.4 Ambient noise is the composite noise from all sources in a given environment excluding the self-noise of the measuring equipment. It consists of sea state, current, precipitation noise (especially rainfall), thunderstorms, fishes, marine mammals, shipping traffic and other anthropogenic sound sources. And it depends on local circumstances as water depth, sea bottom, ice conditions and sound velocity profile. Noise levels are generally expressed as 10 times the logarithm of the square of the ratio of the sound pressure to a reference pressure, defining the sound pressure level. The Sound Pressure Level (SPL) indicates the average amount of sound at one location.

3.5 Shipping noise is the ambient noise component caused by shipping.

3.6 The Sound Exposure Level (SEL) indicates the total amount of sound energy at one location over a certain time duration.

3.7 The Source Level (SL) is the SPL measured in a given radiation direction, corrected for absorption and scaled to a reference distance. It should be independent of the environment. The source spectral density level is describing the source level in different frequency bands.]

4 Predicting underwater noise levels

4.1 Underwater noise computational models may be useful for both new and existing ships in understanding what reductions might be achievable for certain changes in design or operational behaviour. Such models may be used to analyse the noise sources on the ship, the noise transmission paths through the ship, and estimate the total predicted noise levels. This analysis can help shipowners, shipbuilders and designers, to identify noise control measures that could be considered for the specific application, taking into account expected operational conditions. Such measures may include amongst others: vibration isolation mounts for machinery and other equipment, dynamic balancing, structural damping, acoustical absorption and insulation, hull, appendages and propeller design.

[4.2 Types of computational models may include:

- .1 Computational Fluid Dynamics (CFD) can be used to visualize and estimate flow noise outside the hull (i.e. geometry of hull form, appendages, and propeller with respect to cavitations);
- .2 Statistical Energy Analysis (SEA) can be used to estimate high-frequency noise and vibration levels from machinery and hydro acoustics (i.e. propeller) sources transmitted by the ship structure;

- .3 Finite element analysis (FEA) and boundary element method (BEM) may contribute to estimate low-frequency noise and vibration levels from the structure of the ship excited by the fluctuating pressure of propeller and machinery excitation; and
- .4 Lifting surface theory or large eddy simulation method may be considered for the estimation of direct radiated noise from the propeller.

4.3 The value of modelling exercise is greatly enhanced if their predictive capabilities are verified in case studies under different likely operational and environmental conditions.]

5 Standards

5.1 Measurement standard

5.1.1 Underwater noise should be measured to an objective standard for any meaningful improvements. The American National Standards Institute and the Acoustical Society of America (ANSI/ASA) S12.64-2009 "Quantities and Procedures for Description and Measurement of Underwater Sound from Ships, part 1: General Requirements" is available for commercial ships. This measurement standard is for deep water which implies that the water depth should be larger than 150 m or 1.5 times overall ship length, whichever is greater.

[Underwater radiated noise is quantified using the parameter "sound pressure level" (SPL) which is reported in decibels that equal $20 \times \log(p/p_0)$. This parameter is the same as the in air metric, except that the reference pressure (p_0) is different. For water, p_0 is equal to $1 \mu\text{Pa}$ (micro-Pascal) and in air the value is $20 \mu\text{Pa}$. This difference and the fact that air and water have different density and speed of sound values makes comparing between SPL in air and water irrelevant. The metric used to compare a ship's noise levels to another ship or to a criterion has been the sound pressure level (SPL) at 1 m. The reference distance of 1 m is never intended to be the distance at which measurements are performed. The measurements are performed in the far-field (distance such that the ship appears as a point source, 100 m or one times the ship length). Through mathematical adjustment the SPL value at 1 m is determined.]

5.1.2 Relevant standards presently under development are listed in annex 1.

5.2 Existing design references for quiet ships

5.2.1 Several research ships have been designed using the noise specification proposed by the International Council for the Exploration of the Sea (ICES) Cooperative Research Report No.209 (CRR 209). It should be noted that the ICES CRR 209 noise specification was designed for fishery research ships so that marine life would not be startled during biomass surveys; it was not intended to be used as a commercial ship design standard to prevent potential harm of marine life. However, certain design arrangements used to meet ICES CRR 209 may still be useful for new commercial ships to reduce underwater noise.

5.2.2 A number of classification societies have underwater noise rating criteria, which may prove useful as guidance.

6 Design considerations

The largest opportunities for reduction of underwater noise will be during the initial design of the ship. For existing ships, it is unlikely to be practical to meet the underwater noise performance achievable by new designs. The following design issues are therefore primarily

intended for consideration for new ships. However, consideration can also be given to existing ships, depending on the practicality and cost of noise mitigation measures. While flow noise around the hull has a negligible influence on radiated noise, the hull form has influence on the inflow of water to the propeller. For effective reduction of underwater noise, hull and propeller design should be adapted to each other. These design issues should be considered holistically as part of the overall consideration of ship safety and energy efficiency.

6.1 *Propellers*

6.1.1 Propellers should be designed and selected in order to minimize cavitation. Cavitation will be the dominant radiated noise source and may increase underwater noise [20dB] or [by as much as 20dB over the frequency range of 10Hz to 100,000Hz]. Cavitation can be minimized/reduced under normal operating conditions through good design, such as optimizing propeller load, ensuring uniform water flow into propellers (which can be influenced by hull design), and careful selection of the propeller characteristics such as: size and blade design, section, pitch and camber. Considerations for propellers used most commonly on commercial ships include:

- [.1 the use of fixed pitch propellers may be considered in order to minimize cavitation during normal operations. Optimized propellers could be employed in order to control cavitation to achieve optimized propeller efficiency with consideration on minimizing ship noise radiation into water. Even high efficiency propellers on modern ships can cavitate depending on the ship type and transit speed (e.g. single screw containerships above 16 knots, tankers above 12 knots). Technology is available to predict and control tonal components at harmonics of blade rate (shaft speed x number of propeller blades). The broad band noise part of cavitation below 300Hz which dominates deep water background noise is not investigated but it can be assumed that minimizing the tonals will also reduce broad band noise;]
- [.2 the use of controllable pitch propellers may be considered for designs with constant shaft speed when the ship speed is not controlled by shaft speed adjustment but by changing the pitch of the propeller blades. This may lead to unfavourable hydrodynamic conditions with pronounced cavitation at low speed possibly exceeding noise at full speed. [Ships with constant shaft speed may make use of a power-take-off (PTO; i.e. a generator directly connected to the propeller shaft). In such cases, noise can be reduced by allowing some flexibility in shaft speed. The generator could be adjustable or electrically disconnected from ship mains by a converter.]

[6.1.2 Another source of radiated noise could be related to the vortex released at the blade tip and the whole vorticity and turbulence fields occurring downstream the propeller. These important features of the flow field may heavily depend on the operating conditions of the propeller and, very often, also on the rudder location. The possibility to alter in a suitable way these important effects (for example, by an optimized design of the blade tip and the analysis of the hydrodynamic interactions between the propeller and the rudder) could be accurately investigated in view of a hydro acoustic optimization of the propeller.]

6.1.3 Noise reducing propeller design options are available for many applications. However, it is acknowledged that the optimal propeller with regard to underwater noise reduction cannot always be employed due to technical or geometrical constraints [(e.g. ice-strengthening of the propeller)]. It is also acknowledged that design principles for cavitation reduction (i.e. reduce pitch at the blade tips) can cause decrease of efficiency.

[6.2 *Hull form design*

6.2.1 In general, consideration can be given to reduction of underwater noise from new ships through the reduction of turbulence resulting from the underwater hull form. Optimized bow shape, the elimination of abrupt hull changes at the waterline, minimization and alignment with flow of appendages and fittings, minimization of weld projection and plate distortion and smooth paintwork may help reduce resistance and hence turbulence. Hull form optimization using computational fluid dynamics and model testing may contribute to the reduction of both hull resistance and turbulence. As the propeller operates in the wake field generated by the ship hull, the underwater noise from cavitating propellers may be reduced through the reduction of turbulence resulting from the underwater hull form by making this wake field as homogeneous as possible. It could be anticipated that these recommendations may contribute to more efficient fuel consumption and reduced air emission.

6.2.2 Consideration can be given to the investigation of structural optimization to reduce the excitation response and the transmission of structure-borne noise. For example, hull stern structural optimization may be considered with the intention of investigating an increase in the mechanical impedance of the bottom of the stern structure to reduce the interaction between the propeller and stern structure. Vibration-optimized structure for machinery foundations could be considered to reduce the vibration energy input to the hull structure.]

7 Onboard machinery

7.1 *General*

7.1.1 The selection of onboard machinery along with appropriate vibration control measures, proper location of equipment in the hull, and optimization of foundation structures may contribute to both helping to reduce overall underwater noise and reducing onboard noise and vibration.

7.1.2 Designers, shipowners, and shipbuilders could request that manufacturers supply information on the sound levels and vibration produced by their machinery and recommend methods of installation in order to keep noise levels to a minimum.

7.2 *Propulsion machinery*

7.2.1 Diesel-electric propulsion has been identified as an effective propulsion train configuration option for minimizing underwater noise. In some cases, the adoption of a diesel-electric system may facilitate effective vibration isolation of the diesel generators which is not usually possible with large direct drive configurations. The use of high-quality electric motors may also help to minimize vibration being induced into the hull.

7.2.2 The most common means of propulsion on board ships is the diesel engine. The large two-stroke engines used for most ships' main propulsion are not suitable for consideration of resilient mounting. However, for suitable four-stroke engines, flexible couplings and resilient mountings may be considered, and where appropriate, may significantly reduce noise levels. Four-stroke engines are often used in combination with a gearbox and controllable pitch propeller. For effective noise reduction, consideration could be given to mounting engines and gearboxes on resilient mounts, possibly with some form of elastic coupling to the thrust bearing. Resilient foundations are already available for many auxiliary engines.

[7.2.3 Rotary engines (e.g. turbines) will induce less vibration to the hull resulting in less underwater noise. Alternative propulsion systems using water jets, podded propellers, etc., may be considered to minimize underwater noise.]

7.3 *Reciprocating machinery (such as diesel engines, refrigeration plants, air compressors, and pumps):* Consideration may be given for the appropriate use of vibration isolation mounts as well as improved dynamic balancing. Vibration isolation of other items and equipment such as hydraulics, electrical, pumps, piping, fans (large HVAC), vent and AC ducting, etc., may be beneficial for some applications, particularly as a mitigating measure where more direct techniques are not appropriate for the specific application under consideration. Such approaches may contribute to reduction of both underwater radiated and onboard noise affecting passengers and crew (inside working and living spaces).

[7.4 *Large HVAC fans:* Consideration could be given to the isolation of these fans from the ship structure, especially when located below the main deck. HVAC fans may be fitted with variable speed controls, attenuation of the air inlet (sound absorbing mushroom hat), and air inlet with mineral lined suction chamber, labyrinth or absorption chamber.]

[7.5 *Sea pipe systems (such as seawater cooling systems):* The flow induced noise could be analysed and reduced. Flexible hosing may be used to isolate the machinery from the ship structure. Optimizing the layout of the piping system, using elastic supports, fluid mufflers, and flexible structure-borne insulation for pipes for penetrating bulkheads may also be used to structurally isolate the machinery and mitigate fluid noise.]

8 Operational and maintenance considerations

Although the main components of underwater noise are generated from the ship design (i.e. hull form, propeller design, the interaction of the hull and propeller and machinery configuration), operational modifications and maintenance measures could be considered as ways of reducing noise for both new and existing ships.

8.1 *Propeller cleaning:* Propeller polishing done properly removes marine fouling and vastly reduces surface roughness, helping to reduce propeller cavitation. Available information from technical articles indicate that in some cases effective propeller cleaning and polishing may also result in power savings of up to 10 per cent.

8.2 *Underwater hull surface:* Maintaining a smooth underwater hull surface and smooth paintwork may also improve a ship's energy efficiency by reducing the ship's resistance and propeller load. Hence, it will help to minimize underwater noise emanating from the ship. Effective hull coatings that reduce drag on the hull, and reduce turbulence, can facilitate the reduction of underwater noise as well as improving fuel efficiency.

[8.3 *Inspection and maintenance:* Consideration could be given to the inclusion within planned maintenance procedures, of periodic inspections/monitoring of machinery and equipment with respect to any noise control/reduction features. Should such activities reveal defects or areas of improvement, appropriate action can be taken.]

[8.4 *Selection of ship speed:* In general, for ships equipped with fixed pitch propellers, considering the cavitation inception speed of the propeller when selecting ship speed can be a very effective operational measure for reducing underwater noise (i.e. the selected ship speed should be less than the cavitation inception speed).

For such ships equipped with controllable pitch propellers, consideration could be given to optimum combinations of shaft speed and propeller pitch. However, there may be other, overriding reasons for a particular speed to be maintained, such as safety, and energy efficiency, etc. Consideration could also be given in general to any critical speeds of an individual ship with respect to cavitation and resulting increases in radiated noise.]

8.5 *Rerouteing and operational decisions to minimize adverse impacts on marine life:* Consideration could be given to possible speed reductions or routing decisions to avoid sensitive marine areas including well known habitats or migratory pathways when in transit.

[9 Features of technology that may contribute to a quieter commercial ship

A number of features can contribute towards a quieter ship and many measures to improve fuel efficiency are also expected to reduce underwater noise. There is a need for further research and measurements to quantify the expected noise reductions associated with many of the features identified here. This is especially the case for measures that may be applied to existing ships.

9.1 The ship and its propeller could be model tested in a cavitation tunnel for optimizing the propeller design with respect to cavitation induced pressure pulses.

9.2 If predicted peak fluctuating pressure at the hull above the propeller in design draft is below 3 kPa (1st harmonic of blade rate) and 2 kPa (2nd harmonic) for ships with a block coefficient below 0.65, this could indicate a potentially quiet propeller. Comparable values are likely to be 1 kPa higher in ballast condition.

9.3 Diesel generators could be resiliently mounted where found to be technically and cost effective.

9.4 Smaller four-stroke diesel engines (if any) might be resiliently mounted and isolated from the gearbox by a suitable elastic coupling.

9.5 Ships with a controllable pitch propeller could have some flexibility on shaft speed to minimize operation at pitch settings too far away from the optimum design pitch. (Some designs may be able to operate down to a shaft speed of two thirds of full.)

9.6 *Quieting technologies for existing ships:*

- .1 Design and installation of new state-of-the-art propellers;
- .2 Installation of wake conditioning devices;
- .3 Air injection to propeller (e.g. in ballast condition); and
- .4 Installation of active vibration control devices on the diesel engine.]

* * *

ANNEX

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO) STANDARDS

1 The International Organization for Standardization has developed the (ISO/PRF PAS) 17208-1 "Acoustics – Quantities and procedures for description and measurement of underwater sound from ships – part 1: General requirements for measurements in deep water". This measurement standard is for deep water which implies that the water depth should be larger than 150 m or 1.5 times overall ship length (ANSI-ASA engineering method), whichever is greater. This is a temporary public available specification, to be updated to a standard.

2 ISO/DIS 16554 Ships and marine technology – Marine environment protection – Measurement and reporting of underwater sound radiating from commercial ships is being developed by ISO/TC8/SC2/JWG1, is now the final stage and will be published in early in 2013. The final draft text will be available at DE 57 in March 2013.

3 ISO/TC8/SC2/JWG1 will also develop ISO 16554, part 2 for shallow water measurement in 2013.
