MARINE ENVIRONMENT PROTECTION COMMITTEE
59th session
Agenda item 19

MEPC 59/19
9 April 2009
Original: ENGLISH

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 is the report of the Correspondence Group on the issue of "Noise from commercial shipping and its adverse impact on marine life", which was added to the Committee's agenda by MEPC 58 as a high priority item. The Correspondence Group is to identify and address ways to minimize the incidental introduction of noise from commercial shipping operations into the marine environment to reduce potential adverse impacts on marine life. The Committee assigned several sessions to this work and this is the first report from the Correspondence Group.
Strategic direction:	1, 7 and 13
High-level action:	1.1.2
Planned output:	1.1.2.3
Action to be taken:	Paragraph 9
Related documents:	Resolutions A.989(25), A.982(24), A.900(21), A.720(17), and A.468(XII); MSC/Circ.1014; MSC 84/INF.4; MSC 83/28; MEPC 58/19; MEPC 57/INF.2; MEPC 57/INF.4.

Introduction

1 MEPC 58 approved the inclusion of a new high priority item in the work program of the Committee on "Noise from commercial shipping and its adverse impact on marine life." A Correspondence Group was formed under the chairmanship of the United States to progress work on this issue. Several rounds of comments were exchanged. While the work is ongoing, this document summarizes the interactions and progress on this issue thus far. Member Governments were also invited by MEPC 58 to submit appropriate documents to MEPC 59 for its consideration.

2 The following Member States, observer organizations and entities were on the e-mail list for this Correspondence Group, although not all actively participated in the discussions:

Argentina	Italy	Singapore
Australia	Japan	Sweden
Bahamas	Liberia	The Netherlands
Canada	Marshall Islands	United Kingdom
China	Panama	United States
Germany	Republic of Korea	

CLIA	IFAW	IWC
UNEP/CMS	IMAREST	WWF
FOEI	INTERTANKO	
ICOMIA	ISO	
ICS	IUCN	

3 The Committee assigned the following terms of reference to the Correspondence Group:

.1 identify and address ways to minimize the introduction of incidental noise into the marine environment from commercial shipping to reduce the potential adverse impact on marine life, in particular develop non-mandatory technical guidelines for ship-quieting technologies as well as potential navigation and operational practices; and

.2 provide reports to the Committee.

Scope of Work and Basic Assumptions

4 In discussing the scope of work of the Correspondence Group, the following points were made. First, it was recognized that the Correspondence Group would focus on the incidental introduction of underwater noise from commercial shipping and thus would not look at the introduction of noise from sources such as military ships or the deliberate introduction of noise for other purposes such as sonar or seismic activities. Second, the Group is focusing on underwater noise although it was noted that there may also be tangential benefits of any noise-reduction efforts for airborne noise and structural vibration affecting persons aboard vessels. Third, the Group began its focus on possible ship maintenance, retrofit, design, and construction issues rather than addressing matters of biology and acoustic impact per se. Finally, while the terms of reference for the Group include "potential navigation and operational practices", it was decided that this element would be discussed at a later stage after concentrating on ship design and construction and how quieting technologies may be integrated into these elements.

5 Several basic assumptions were set forth at the outset of the discussions by the Correspondence Group to guide its work:

.1 as evidenced in MEPC 58/19 and the acceptance by the Committee to include this issue on its agenda, there is now a valid scientific basis for concluding that commercial shipping noise has—at some level—the potential to disturb behavior or interfere with critical life functions of marine life (e.g., marine mammals, fish);

.2 there is no need to debate the extent of the potential impact of noise spatially, temporally and biologically. It was recognized that there are many underlying complexities, variability, and some areas of uncertainty. These issues are open to debate within the scientific community and, since IMO's work is focused on shipping, that is where we should focus our work;

.3 at the outset of the discussions, we should not make a distinction between existing and new commercial ships, but look at various technological and/or engineering solutions for each, some of which may be common to both;

.4 options for quieting noise from commercial ships should be evaluated relative to the amount of reduction achievable (probably a range based on ship and propulsion type), the cost of implementing a particular reduction strategy (new ship, existing ship) and any collateral benefits (e.g., greater fuel efficiency, reduced carbon footprint, reduced maintenance and operational costs, reduced noise exposure aboard vessels for crew and/or passengers);

.5 the options for quieting technologies generally fall into two basic areas: hull/propeller design (cavitation) and underwater radiated noise from machinery, but other possibilities may exist which will hopefully be identified by the Group. The initial and primary focus of the Correspondence Group's efforts is expected to be on issues related to propeller cavitation since propeller cavitation as it is known to be a significant (and often dominant) source of underwater noise from large vessels;

.6 after addressing quieting technologies, other issues may be pertinent such as: the overlap of dense shipping and migratory pathways, and establishing integrated underwater noise monitoring systems; and

.7 we are working on the basis for developing *non-binding*, technical guidelines. Our goal is to develop practical, effective guidance on solutions that can reduce the incidental introduction of underwater noise from commercial shipping in turn reducing potential adverse impacts to marine life.

6 Not surprisingly, in discussing these basic assumptions, the issue of the interplay between the impact on marine life and incidental noise from commercial ships generated interest. As described above, it was noted that the overarching goal of the Group is to focus on the minimization of the introduction of this incidental noise to reduce the potential adverse impact on marine life. However it was also acknowledged that how noise can impact marine life is highly dependent on the context of exposure and the species in question; there is and will remain some degree of scientific uncertainty regarding the exact nature, magnitude, and significance of shipping noise impacts on various marine animals. It was noted that this uncertainty should not preclude working on the issue of quieting technologies for commercial ships. Rather, this should remain an active area of research proceeding in parallel with and informing efforts to reduce the acoustic footprint of commercial vessels. It was also recognized that there may eventually need to be links between specific types of adverse impacts to specific marine animals and specific types of incidental noise from commercial ships. This issue will undoubtedly come to the fore when the Correspondence Group focuses on evaluating the effectiveness and cost of a particular quieting technology or technological solution; an important part of that evaluation will be the potential for effectively alleviating adverse impacts to marine species.

Research

7 A number of documents, the titles of which are set forth in annex 2 to this document, were circulated to the Correspondence Group for background information.[1] Several members of the Group stressed that we should not attempt to redo the work in these papers, but draw upon them in our work. It was also recognized, however, that there is a need for more research in this area; however, any such work should be done simultaneously with the work of the Correspondence Group and it should not stand in the way of moving forward with our efforts. Indeed, during the discussions, the International Fund for Animal Welfare submitted to the Correspondence Group for comment an outline for a systematic review of existing technologies aimed at identifying practicable and cost-effective strategies. This review is expected to be completed in April 2009. The Group noted that further areas of research may be identified as our work continues.

Substantive Questions

8 The bulk of the work of the Correspondence Group was responding to a series of questions posed by the Correspondence Group chairman. These questions, consistent with the scope of work and basic assumptions, focused on technical questions. The list of question with the responses received from Correspondence Group members is at annex 1 to this document. The Group will draw upon these responses in proceeding with its consideration of this issue.

Action requested of the Committee

9 The Committee is invited to consider the report of the Correspondence Group and take any action it deems appropriate.

***

[1] These documents are available electronically from the Chairman of the Correspondence Group: Lindy.S.Johnson@NOAA.GOV .

ANNEX 1

IMO NOISE REDUCTION TEAM SUMMARY OF COMMENTS[1]

1 What are the most important sources of low frequency (less than 1 kHz) radiated underwater noise from commercial vessels?

- Propeller: Cavitation (broadband but generally low-frequency) and blade rate tonal (narrow-band and also generally low frequency) sounds are a dominant source of underwater noise and should be a key focus of the Correspondence Group. Another participant stated that it appears that there is consensus that a primary source of external noise from ships is cavitation. This is predominantly blade rate harmonics due to propeller cavitation and wideband cavitation noise. Radiated noise due to propeller cavitation at frequencies <100 Hz is the predominant underwater radiated noise at higher propeller loads. Depending on the pitch setting and loading of a propeller, a CRP propeller may generate higher frequency noise.

    - o *Southall 2005:* Most (83%) of the acoustic field surrounding large vessels is the result of propeller cavitation.
    - o *Southall and Scholik-Schlomer 2008*: Previous measurements from the U.S. Navy's Southeast Alaska Acoustic Measurement Facility (SEAFAC) on cruise ships (similar propulsion systems as large commercial vessels) indicate that principle sources of noise result from the propulsion system and the propeller. Spectrums of representative vessels were provided showing that propulsion systems mainly contributed to frequencies below 1000 Hz, while those above 1000 Hz were from the propeller.
    - o *Southall and Scholik-Schlomer 2008:* SEAFAC studies indicate propeller-radiated noise is highly dependent on vessel speed.
    - o *Rousell (2002 ACCOBAMS report) cites Clark (1999); see also Richardson el al*: In regard to the sound contribution of increased large vessel traffic, Rousell cites Clark as saying propeller noise is the primary source of sound increases in the frequency band below 100 Hz.
    - o *Hatch et al. 2008:* Within the 10-1000 Hz range (concentrations in the 10 to 400 Hz band) in the high traffic locations in Stellwagen Bank National Marine Sanctuary where commercial vessels accounted for 78% of tracked traffic, there was double the acoustic power of that in less trafficked locations during the majority of the time period analyzed (2 months in 2006).
    - o *Wright 2008:* Thrust loading and non-uniform inflow generate conditions at certain points along the path of the rotating propeller blades where water vapor bubbles (i.e. cavitation) are rhythmically formed.

- Machinery: Main diesel engines as well as auxiliary diesel engines are important sources of noise owing to their potential to induce structure-borne vibrations that radiate via the hull. Hull induced vibration generated by the operating machinery at frequencies <100 Hz is the predominant noise source at lower vessel speeds. Reduction gears of medium speed engines may generate noise at much higher frequencies >1 kHz. One participant noted that machinery noise starts to become significant for vessels operating at low speeds (i.e. with low prop loadings as in harbor approaches). Another noted that although machinery-generated

[1] One participant noted that some of these statements needs to be reviewed in light of targeted research and reliability of data on which they are based.

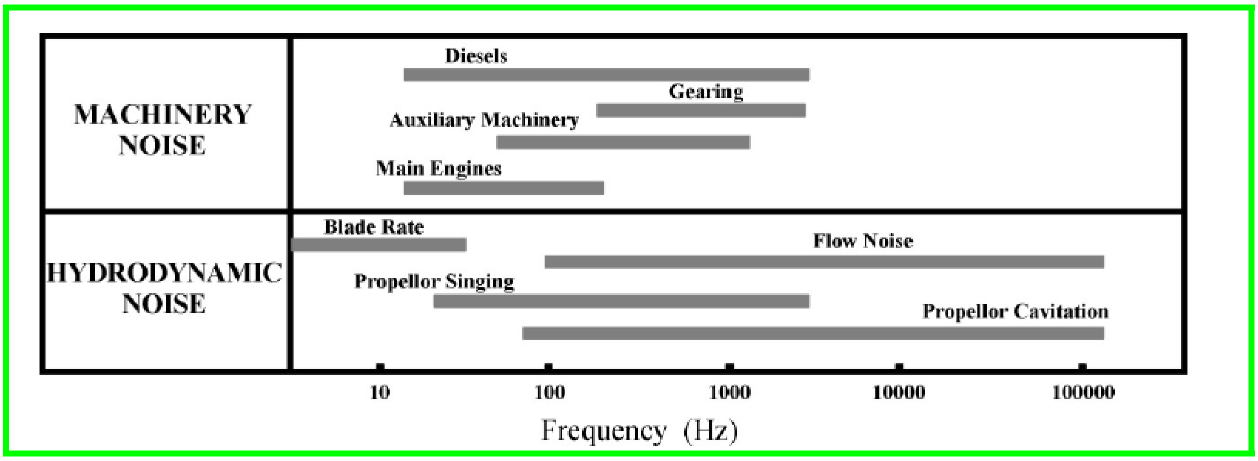
noise radiated through the hull is a source of underwater noise, it is less clear how significant it is as source of the total external noise generated; the range of the noise source and the inverse square law need to be taken into account.

- o *Wright 2008:* Primary sources of machinery noise are propulsion engines and ship service generators.

- Appendages: Noise generated due to flow around appendages are of low intensity at frequencies below <20 Hz. One participant questioned whether we should be more explicit as to what kinds of appendages would be more of an issue or at least provide some examples.

  - o *Southall 2005:* Flow noise around the hull is generally minimal compared to that generated by propeller cavitation and machinery noise, but plays an increasingly significant role at low frequencies as vessel speed increases.

- MEPC 58/INF.19 cites Norwood (nd) for the following table:



1a For each source type, please address the following, if applicable, and if known: the characteristics of this source of noise and the conditions under which it has been evaluated (i.e. frequency and intensity estimates and measurement conditions)

- The sources listed above in response to question 1 generate both continuous and transient narrow and broad band noise. Blade rate harmonics are due to propeller cavitation, while main engine firing rate and auxiliary diesel generators are tonal noise components. Cavitation is a broadband noise source and, in addition to the blade rate harmonic series, it consequently generates a continuous spectrum, predominately at low frequencies. This spectrum has a broad "hump" at low frequencies (about 50 Hz) followed by a continuum that decreases by 6 db per octave. This wideband cavitation noise is strongly amplitude modulated at blade rate frequency, which produces a characteristic sound when listening to underwater noise recordings. At high speeds the continuum can contribute a significant fraction of the radiated noise power.

1b For each source type, please address the following, if applicable, and if known: the degree to which this source of noise is currently evaluated during the ship design phase or final builds for ships (i.e. not at all, on a few ships, on many ships)

- Noise sources such as diesel engines and propellers are usually considered during the design of commercial ships with respect to noise levels inside the ships. Vibrations of individual operating machinery and accommodation spaces are measured routinely for preventive-based maintenance.
- Radiated underwater acoustic level are generally only evaluated during the design phase in particular for specialist ships and then only upon request.
- Noise is addressed during the design/new construction of ships to the extent it is necessary to achieve acceptable noise levels within accommodation and other spaces. Due to additional costs (either initial construction or operating) external noise generated by a ship is addressed if its service (e.g., warships, fisheries research vessels, or survey ships) makes it necessary to do so.

    - *Southall and Scholik-Schlomer 2008:* Very few engineers and architects from within the industry have begun to assess and attempt to engineer ways of reducing underwater radiated noise; noise has always been thought of in terms of passenger/crew health, safety, and comfort.

1c For each source type, please address the following, if applicable, and if known: the degree to which this source of noise is currently addressed in final builds for ships (i.e. not at all, on a few ships, on many ships)

- In response to this question, responses were submitted that said same as 1b.

1d For each source type, please address the following, if applicable, and if known: the relationship between the magnitude of this source of noise and the regularity of specific ship maintenance tasks

- The only reason for change of propeller noise behaviour is damage to the propeller causing a change of its hydrodynamic shape, or marine growth. Damage does not usually go unnoticed and there is a great interest in correction. Marine growth is not likely because of the very high usage of ships (in the order of around 360 days a year). For example, growth of barnacles on the surface of a propeller can occur if the propeller does not turn for a longer period of time (at least several days to weeks). Barnacles cause premature and more severe cavitation which may go unnoticed if it is not in conflict with obvious loss of performance of the ship. Damaged and therefore cavitating propellers are usually repaired during drydocking and when pitch may be checked and readjusted.
- Excessive vibrations generated by the machinery and piping onboard vessels are routinely corrected.

1e For each source type, please address the following, if applicable, and if known: the relationship between the magnitude of this source of noise and ships' operating conditions (i.e. speed, loading)

- The relationship of the magnitude of radiated noise due to propeller cavitation and vessel speed should be researched. Generally, lower vessel speed and propeller loading will reduce propeller cavitation and hence the radiated noise. Propulsion systems with controllable pitch propellers (CPP) might be an exception in this regard. Medium speed diesel generators have been found to sometimes contribute considerably to radiated noise above 50 Hz when not masked by cavitation noise.

    - *Wright 2008:* For certain types of ships speed is not controlled by adjusting the rate of propeller rotation, but rather by adjusting propeller pitch and keeping shaft speed constant. This may lead to cavitation at speeds other than those for which the ship was specifically designed. The relationships between propeller pitch settings, propeller loading, and other propeller design parameters need to be investigated with respect to underwater radiated noise.
    - *Southall 2005:* Trends in vessel propulsion systems are advancing toward faster ships operating in higher sea states for lower operating costs.

- Additionally, data available so far implies that ships in ballast produce more cavitation noise than in fully loaded conditions. This is due to shallower propeller immersion.

    - *Southall 2005:* There is significant aspect dependence on radiated vessel sound fields with sound levels being approximately 10 to 14 dB lower off the bow and stern compared to off the side of a ship.
    - *Southall 2005*: Source (propeller) depth is also important in terms of long-range propagation. This is a potentially significant historical factor in ambient noise trends due to shipping, as propeller depths have increased with increasing vessel size.
    - *Southall 2005:* Noise from container ships is expected to become more significant along certain routes in the near future.

- Machinery-induced noise may remain nearly constant at lower vessel speeds. For example, diesel generator noise is not dependent on ship operating speed.

1f For each source type, please address the following, if applicable, and if known: whether this noise source remains significant for ships that are hoteling, in port or otherwise stationary

- In harbor, cavitation noise is dominant during manoeuvring conditions while diesel generator noise mostly prevails at low speed both in harbour and at berth.
- In stationary conditions, the propeller generated noise will be nil. The hull induced noise would be generated by the operating machinery. On a stationary vessel with the main engine on standby, more auxiliary machinery will be in operation as compared to when the main plant is shut-down.
- In port, electrical load for hoteling may be produced by the onboard power plant or by the shore power. On "cold ironed" vessels not having cargo operation, noise generation would mainly be from the HVAC machinery, and minimal in intensity.

- One participant questioned why we are even considering noise in port and port maneuvering and suggested that these aspects should be deleted from the Group's consideration. It was felt that if this issue were to be covered then we should also assess port machinery and equipment, shore-based industries, the leisure industry, and other things that are based in the port area.

  - *Roussel (2002 ACCOBAMS report)(specific examples provided in report; see also Wright 2008 citing several other studies)*: Coastal areas are places where human-made ambient noise is the loudest, notably around harbors due to intense traffic often converging in these areas.

2 What kinds of technologies are currently used to reduce radiated underwater noise from vessels of all types, including non-commercial vessels (e.g., oceanographic research, fisheries, military (non-sensitive information of course!), or other types of vessels)?

- Much has been done to silence warships, in particular submarines but at a significant developmental and procurement cost, and oceanographic research vessels; much of the focus (at least initially) has centered on modifications to propulsion systems.
- While there are many possible treatments, some of which have proven effective in a variety of applications, almost none of these have been applied on the largest categories of vessels. Thus, the extent to which any technology may be relevant or appropriate to very large vessels remains unclear. One participant thought that this point was critical for the Group's understanding; that is, that there have been things used in smaller vessels and other applications that have not been attempted to be used on large ships.
- Main dimensions of the hull and the hull/propeller interaction are optimized to improve the wake field around the propeller and to reduce hull resistance. Twin screw propulsion and wing thrusters are used to good effect on specific hull forms and propulsion.

  - *Wright 2008:* Twin-screw ships may have smaller propeller loadings and a more homogenous wake field, therefore better working conditions for propellers. As a result, propeller cavitation, and hence the noise it produces, is reduced compared to single-screw ships.

- To reduce cavitation, surface piercing, non-cavitating and advanced blade section propellers are often used. Besides the twin screw ships, electric and Voith-Schneider propellers have the potential to reduce propeller-induced vibration. Contra-rotating propellers, propellers with tip (Winglet) and ducted propellers are also used to improve propulsion efficiency.

  - *Southall 2005; Southall and Scholik-Schlomer 2008:* Propellers designed to minimize cavitation may have: tips without added weight, large diameters (tip speed is reduced and cavitation occurs at higher speeds; larger propellers can be expensive), low RPMs, long blade lengths, bulbs on the tips, and/or refined trailing edges. Additionally, variable pitch propulsion systems will produce (very) high sound levels when used outside their designed pitch. Optional configurations of propellers, such as placing them deeper in the water column through use of propeller pods, are also used to varying degrees in designing quiet vessels.

- *Southall and Scholik-Schlomer 2008:* A more feasible solution to cavitation may be to concentrate on the wake field (inflow field) and propeller design. The more homogenous the wake field surrounding the blades, the quieter the propeller will operate. Propeller fins can reduce vortex bursting and may offer as much as a 12-dB reduction for various harmonics.
- *Southall and Scholik-Schlomer 2008:* Propeller modifications to reduce noise include (See also the Table on pages 30-32 of *Southall and Scholik-Schlomer 2008* for detail on specific design options for vessel quieting):

  - Single screw systems with open (high) screw propulsion to allow for a smoother (less turbulent) wake field;
  - Forward-skewed nozzle-propeller blades to allow for an increase cavitation inception speeds and reduction cavitation on the leading edge of the blade;
  - Twin screw propulsion systems to allow for reduced tip speed, which results in lower cavitation more readily than single screw systems (these systems also provide increased operational safety in having a redundant mode of propulsion);
  - Azipod propulsion (azimuth electric propulsion drive) systems to allow for an improved wake field, greater hydrodynamic efficiency, and ultimately less cavitation and noise, although motor (mechanical) noise generated from azipods is an important consideration in their overall effectiveness, as is their potential application on very large vessels; and
  - Water-jet propulsion, a relatively well-known type of quieter propulsion system, is especially encouraging since short sea shipping and other inter-coastal means of transport will mainly rely on this type of propulsion capable of attaining speeds as high as 24 to 40 knots (water-jet efficiency is greater at higher speeds; poorer below 15 knots).

- Vessels' equipment and propulsion systems may be fine-tuned to achieve more appropriate harmonics, thereby reducing vibration which might be transferred to the hull.
- Underwater appendages are streamlined and the rudder (rudder bulb) and skeg designs are optimized to improve the flow of water around the appendages and to reduce drag and noise.

  - *MEPC 58/INF.19 citing Norwood nd*: Hull design is important in controlling noise, particularly through the reduction of turbulence-elliptical bow shape, no abrupt change of shape in the waterline, minimization and alignment with flow of appendages and fittings, flush welds, undistorted plates and smooth paint work.

- Hull cleaning/silicon based coating has the potential to reduce hull resistance and reduce propeller loading.
- Paint systems may help to improve ship efficiency but would not improve noise reduction to a substantial degree.
- Noise cancelling devices may effectively reduce the noise generated by a vessel. Another participant suggested that this bullet be deleted because it is too generic and therefore not useful. It was also thought that this is more appropriate to airborne noise.
- Other ways to reduce noise are through resilient mountings for medium speed engines and auxiliary machinery.

- Variable speed pumps, optimum electric load control (to reduce the number of auxiliary engines operating for power generation at a given time) have the potential to reduce auxiliary machinery generated vibrations.

    - *Southall 2005:* Acoustic filters, desurgers, and flow control valves may also be used to minimize sound emanating from fluids flowing to and from engine equipment.
    - *Southall 2005:* Electric drive propulsion may result in relatively low machinery radiated noise for those ships where it is economically feasible, provided the system has a high-quality acoustic power supply. Electric (AC) drive is being increasingly used in cruise ships and is being considered for large, high-speed container ships. Electric drives may have a greater initial cost than mechanical or direct drive propulsion, but for some applications provide greater overall fuel economy.

- Hybrid power generation using fuel cells and/or a combination of solar, wind and shore power will reduce the total machinery induced vibration.
- Pod propulsion systems (some models include diesel electric systems housed within the ship which supply electric power to a motor housed in the pod) have the potential to alleviate these problems by:

    1) allowing power generation to occur in smaller power plants which may be mounted in a more shock/vibration absorbing manner;

    2) avoiding the use of long propeller shafts; the shaft utilized by the system dwells within the pod and is much shorter in length;

    3) allowing power plants to be mounted in a part of the ship which is less likely to conduct sound into the marine environment/other spaces;

    4) *Southall 2005:* Pod propulsion systems can provide minimum disturbed flow to the propeller, which greatly reduces propeller cavitation; and

    5) *Southall 2005:* some podded propulsion systems may have lower radiated underwater noise levels, this depends strongly on the type of power supply involved.

- Both warships and research vessels have an acoustic specification in view of radiated noise and sonar self noise when equipped with sonar. However, in almost all cases an acoustic specification exists for non-cavitation conditions. The ships in question are generally twin-screw with fair lines. Research vessels are particularly low speed, i.e. from zero speed (drift) to 16 knots. Warships are typically specified from 10 to 20 knots, although their maximum speed may be 30 knots.
- At higher speeds, improvements may be achieved if a ship is equipped with the "Prairie-System" which involves blowing air into the flow around the propeller through tiny holes in the blades which dampens the collapse of the cavities.

- In looking at this question, one participant noted that of the solutions that have been employed to reduce external noise on these special purpose vessels, the Correspondence Group should keep in mind which ones that:

  1) can reasonably/practicably be employed on a *merchant* vessel; and

  2) will have a meaningful impact on reducing external noise in the frequency band of concern.

To what extent could such technologies potentially be used on commercial vessels? Please indicate the following in response to this question:

2a the characteristics of the vessel to which the technology is currently applied and a description of the technology. Characteristics provided should include vessel type, length/breadth, (maximum and minimum) draft, deadweight, propulsion type, maximum design speed and typical route (if one exists)

- Generally, noise reduction measures applied to navy and/or research vessels would be expected to also be useful with regard to commercial vessels, although this remains in large part an open question.
- Information about noise cancellation technology may still be classified.
- Low noise propellers: there is no general difference between a commercial ship propeller and a propeller for a warship or a research vessel, other than sometimes that of scale. However, the design criteria and construction standards for the propellers of commercial ships and military ships differ.
- Resilient mounts: this is an introduction of springs between a noise source and its foundation. In warships all machinery is already resiliently mounted to reduce the effect of shock due to such things as underwater explosions. Because of the completely different propulsion plant design related to commercial ship machinery there are obvious limits. However, the so-called double stage mounting system is an option to reduce noise transfer from diesel generators to ship structures to a substantial degree. One participant thought that this could be done with relatively little expense while another disagreed.
- Resilient mounting of secondary propagation paths such as piping: This is almost always done for the ducts of the exhaust gas system in all ship types. For other piping this is only helpful if other propagation paths are treated for structure-borne noise from primary sound sources. One participant noted, however, that it only requires one “short-circuit” of a resilient mount to completely negate all other precautions.
- Airborne noise insulation: this means cladding of a quiet ship’s interior to avoid excitation of the structure by airborne noise or direct transfer to outside. This only makes sense if the major propagation paths have been treated at a high level. Even if an average commercial vessel is silenced by 20 dB, this measure would still not result in an effect on underwater radiated noise.
- Damping treatment to structures: this is a very general measure sometimes used in the past on warships and research vessels, and is not effective for low frequencies. As research has shown, it has a very limited effect and is today reduced to singular measures in special cases at already very low levels.

- Active mounting systems: Today, these can be considered proven and commercially available but not universally used to quiet ships, even for military applications. It only makes sense if the major propagation paths have been treated at a certain degree. These might be helpful in certain special applications in commercial ships but some additional research is required.
- For growing ship sizes, twin-screw propulsion might help to improve noise reduction by reducing propeller loading. With experience this might be applied also for smaller ship types.
- Air bubble systems are used to reduce cavitation noise on some warships. This technology may be extended and simplified to suit ships with high level cavitation noise as well.
- Engine synchronization is being used by ferries in the Puget Sound Area and there is potential for application to vessels operating with one shaft and multiple engines.
- A trend in warship and research vessel design (and in passenger ships as well) is the use of diesel-electric propulsion systems. These are potentially much quieter than such things as direct diesel drive; however, they have no effect on cavitation noise.
- Due to cost considerations, model tests to optimize hull dimensions and to determine hull/propeller interaction are done for new types or classes of commercial vessels. Optimized hull, streamlined appendage and improved propeller designs are used to improve the propelling efficiency. The single screw vessels, tankers and bulkers, are usually limited to the application above technology. Twin screw vessels used for passenger, ferry and specialized vessels, having diesel-electric or medium speed diesel propulsion engines, can be fitted with resilient mountings on the main propulsion engines to reduce vibration.
- Commercial vessels have a wide variety of ship types, sizes, DWTs, drafts, speed/power. The vessels are usually designed and optimized for specific trade routes. Thus, it would be difficult to itemize the information requested. Some of the vessels are characterized as:

Capesize	~ 80.000 dwt and greater	~ 42 m width
Panamax	~ 60.000 to 80.000 dwt	~ 32 m width
Handymax	~ 40.000 to 60.000 dwt	~ 30 m width
Handysize	up to 40.000 dwt	~ 23 m width
Barges	all sizes	~ all sizes

- In response to this list of ship types, one participant stated that these categories and notations are valid only for tankers and bulkers and it was therefore suggested that we either list all ship types and their respective categories or this list be removed because it is arbitrary and covering only a certain range of full block ships.

2b the driving force for the development of current technology (e.g., has it been developed to address another issue such as anti-fouling paints on propellers or technologies to make a fisheries research vessel quiet in order not to scare away the very thing being researched)

- To improve the vessel operating efficiency or to comply with the regulatory requirements.
- To reduce the noise and vibration impact on the crew (IMO A.468(XII).
- Noise in passenger vessels is reduced to improve passenger comfort.
- To prevent damage to the mounted equipment or nearby equipment from vibration.

2c the noise source onboard the vessel to which the current technology is being applied (e.g., propeller, onboard machinery, engine)

- For vibration and noise all relevant sources like propeller, main and auxiliary diesel engines and their exhaust gas systems as well as air conditioning are considered during ship design.
- Active mounting systems are currently applied to diesel engine installations on mega-yachts. This technology might help to reduce machinery noise also on commercial vessels. However, it is not suitable for high power machinery.
- Resilient mounting addresses vibration from auxiliary machinery, compressors, hydraulic units, generating sets, vents, exhaust pipes, and silencers.
- Main engine noise addressed by synchronization of pistons, thus reducing the effective duty cycle of the total engine as a sound source.
- A variety of noise sources (structure borne and engine) could be reduced or eliminated using pod propulsion (conventional engines have not been seen as presenting the opportunity for resilient mounting that can be done with smaller equipment to dampen the transfer of noise, due to the need for these engines to avoid any extraneous movement to ensure that the shaft remains in line with the engine and the sheer size of the equipment; use long propeller shafts and the length of the shaft and its location predispose it to vibration; are limited in their positioning to the area by which they can be connected to the propeller by the propeller shaft).

    - *Southall and Scholik-Schlomer 2008*: Advanced noise treatments can include hull coating to dampen radiated noise at the ship-water interface and placement of buffering air layers under or within the hull. Both of these treatments can reduce noise by as much as 10 dB. Though, effectiveness of hull coating depends on thickness and air layers are only effective for mid- or high-frequency noise. Maintenance issues are a consideration for both.
    - *Southall 2005:* Many of the quieting technologies require some degree of maintenance to ensure continued performance at optimal quieting levels.
    - See also the Table on pages 30-32 of *Southall and Scholik-Schlomer (2008)* for detail on specific design options for vessel quieting.

2d whether the technology is commercially available

- Except for fuel-cell and hybrid power generation, which are being developed, the technology discussed is commercially available, although relatively little of it has been applied in the context of very large vessels.
- For pod propulsion systems see Rolls Royce Mermaid at http://www.rolls-royce.com/marine/products/propulsion/electrical_pod/d efault.jsp One participant suggested deletion of this bullet because in general pod propulsion systems are comparable with all other diesel-electric propulsion drives only that they have electric propulsion motor in a gondola. Furthermore, such systems are and will be used only for very special applications (mainly cruise ships, medium size icebreakers, research vessels, etc.).

2e the cost and feasibility of applying the technology to existing commercial ships (in the context in which they have already been applied)

- Depending on the type of technology application, the cost to retrofit an existing vessel for noise reduction is comparatively high. For example, a conventional propeller may be replaced by a specially designed non-cavitating propeller comparatively easily during regularly scheduled dry-docking. However, this modification would be cost prohibitive if planned as a stand-alone event. Another participant noted, furthermore the need to assess and address the balance of the whole propulsion train should be considered in order to maintain overall efficiency.

    - See also the Table on pages 30-32 of *Southall and Scholik-Schlomer (2008)* for detail on specific design options for vessel quieting.
    - *MEPC 58/INF.19 citing Norwood nd*. If a vessel is to meet specified noise requirements, then these requirements need to be clearly defined and incorporated during the design phase, as retro-fitting noise control treatments can cost two to three times what it would have cost during construction, as well as taking additional installation time and adding weight to the vessel.

- Well designed resilient (active) mounts will help to reduce diesel generator noise. The technology seems to be applicable also to existing ships, as long as enough space is available. Sound reducing encapsulation of diesel generators has also to be taken into account.
- When discussing whether the air bubble systems which are used to reduce cavitation noise on some warships could be extended and simplified to suit commercial ships with high level cavitation noise, it was noted that such systems are rather expensive and have to be maintained intensively.
- In the view of one participant, the Group must have access to good sources of cost/benefit information when developing the guidelines. Information that simply states that it would be too costly to undertake a particular noise quieting technology does not sensibly inform the work being undertaken by the Group. Validated quantitative cost data must be used where available. This statement was supported by several other participants. One participant, in noting their support, stated that while cost-effectiveness is an important element, the Group should not rule out any noise reducing measures simply based on expense. Validated data is necessary, where available.
- One participant reminded the Group that there is a concern that investments in noise reduction measures that have been used on navy and/or research vessels may be applied to commercial vessels only at a high cost.
- It was noted by one participant that cost issues have not yet been extensively discussed by the Group and this issue will obviously require much more in-depth discussions.
- Another participant noted that while commercial and economic interests must be considered when taking into account the Group's terms of reference, they are only part of the consideration. When discussing these elements, this participant stated that the Group would have to bear in mind that many countries have obligations to reduce disturbances to cetaceans and other marine life under other instruments, which may require a precautionary approach.
- One participant suggested that in future discussions of the cost-benefit analysis, consideration be given to the collateral detriment as well collateral benefit. For example, if additional material adds weight and increases the draft of the vessel or if relocation of pipes reduces usable space or decreases safety, these points should be considered.

2f the cost and feasibility of applying the technology to newly-built ships (in the context in which they have already been applied)

- The application of noise reducing measures for new builds is probably much more cost effective and efficient than additional measures on already existing vessels.

  - *Southall 2005:* Reducing flow noise around the hull is most effectively dealt with at the design phase in which flow measurements and engineering are conducted.
  - *Southall 2005: Southall and Scholik-Schlomer 2008:* Vessel quieting with "standard" reduction measures will likely require only a small increase in cost. The costs associated with noise-reduction efforts might be partially or fully balanced by reduced maintenance costs and increases in vessel efficiency over the approximately 20-30 year average commercial vessel service.
  - *Southall 2005:* Advanced propeller design may represent one of the more economically feasible options in terms of vessel quieting.
  - See also the Table on pages 30-32 of *Southall and Scholik-Schlomer (2008)* for detail on specific design options for vessel quieting.

2g is this technology appropriately applied to reduce underwater noise from ships that are hoteling, in port or otherwise stationary?

- Any technology that targets propulsion systems will not be as useful while ships are in port or otherwise stationary.
- Quieting techniques that target machinery noises are likely to be equally important while ships are stationary as when they are underway.

3 What additional technologies for reducing radiated underwater noise from vessels are currently in research and development or should be advanced through research and development? Please indicate the following in response to this question:

3a the type of vessel to which the technology will be applied (e.g., propeller cavitation, machinery) and a description of the technology

- Optimum hull design, improved hull propeller interaction and propeller design, and streamlined appendages are researched and used to improve the operating efficiency of large commercial vessels. Application of some of the new technology is more geared to a particular class and size of vessels, such as the propeller-rudder combinations to reduce drag are generally designed for tanker, container and Ro-Ro vessels; the propeller tip winglets are used for tanker and container vessels.
- Hybrid auxiliary power generation may be applied to all types and classes of vessels. Diesel–electric propulsion may have more applications to reduce vibration and radiated underwater noise. The use of resilient mountings for medium- and high-speed diesel engines, variable speed pumps, hybrid power generation and power optimization has the potential to reduce vibration and hull induced underwater radiated noise.

3b the driving force for the research and development of the technology (e.g., noise reduction, fuel efficiency, response to adoption of other shipping-related regulations such reduction of air pollution)

- To reduce the contribution of commercial shipping to the ever-increasing prevalence of low-frequency noise in many marine environments (and thus enhance conservation efforts), improve the overall operating efficiency of a vessel and to comply with any relevant regulatory requirements.
- The issue of understanding and minimizing impacts of shipping noise on marine mammals has been considered extensively by international symposia and expert panels (e.g., *NRC 2000, 2005; Southall 2005; Southall et al., 2007; Southall and Scholik-Schlomer, 2008; Hamburg workshop (Wright 2008)*).

3c the noise source onboard the vessel to which the technology will be applied (e.g. propeller, onboard machinery, engine etc.)

3d whether the technology is being considered for application to existing as well as new ships

- Both, but mainly to new vessels.

3e the estimated cost and feasibility of applying the technology to existing and/or new ships

- The estimated costs and feasibility of application of the technology will have to be analyzed and balanced against the expected benefit. These issues may be known in certain contexts for application on smaller craft but it remains a looming hole in available knowledge.

3f whether this technology could be appropriately applied to reduce underwater noise from ships that are hoteling, in port or otherwise stationary

- Hybrid power generation, application of fuel cells and/or use of shore power will greatly reduce machinery generated hull induced underwater noise.

3g are there any obstacles to the development of this technology and, if so, how are they being addressed?

- There are some obstacles to the use of shore power, such as the availability of ample power at each berth at the required frequency and voltage, or the ability to convert the available power to that required on board. Also the availability of required hoisting and connecting power cables either onboard or ashore are other factors. Shore power connection is not simple and requires careful attention in terms of crew/personnel and synchronization of rotating machinery.
- The application of new technology is primarily dependent on cost considerations and applicability. One participant noted that this statement is only true if weighed against countries' conservation obligations stemming from other frameworks.

4 General Comments:

4a One participant noted that there are a couple of things that could be done to help identify the most important noise sources in general terms.

1. Global ship noise forecasting. There is probably enough generic ship noise data available historically to be able to estimate the contribution made by shipping to ambient noise over the last one or two decades. This could be linked to shipping volume data and forecasts for shipping volume, speed and type changes, to predict the noise increase due to shipping over, say, the next decade. If the threshold noise level at which this affects marine animals were known (and currently we understand that it is not known), then that would tell us when a problem is going to arise. This would help with scheduling the introduction of any IMO guidelines etc.

   - *MEPC 58/INF.19 citing Cato and McCauley 2002:* It should be noted that ambient noise in Australian waters (and southern hemisphere, in general) is substantially different to that in waters around North America and Europe due to lower levels of shipping traffic.
   - *Andrew et al. 2002:* Data from the California coast indicates an increase (~10 dB) in ambient noise from the 1960s (1963-1965) compared to the 1990s (1994-2001) in the range of 20-80 Hz which is probably due to increases in commercial shipping over that time period.
   - *Heitmeyer et al 2004; Hatch et al 2008; McKenna (unpublished data):* Models for ship density predict that up to ten ships populate each degree-square along the U.S. Eastern Seaboard (Heitmeyer et al. 2004). Recent studies examining high-resolution ship tracking data have shown transiting rates for key US coastal environments ranging from ~3500 transits (Hatch et al 2008) to ~15,000 transits (McKeena unpublished data) per year.
   - *Hamburg workshop (Wright 2008*) suggested a 3dB reduction in ambient noise in the band of 10-300 Hz in 10 years and 10 dB in 30 years.

In response to the initial comment, one participant noted that modeling the predicted contributions of noise from shipping in ocean basins based on ship density information has been a focus of intensive effort for some time (publications date from 1970s) in defense contexts, where marine engineers must understand and predict ambient noise conditions to fine-tune passive and active acoustic technologies. For example, see:

1) http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?arnumber=1151616, and Historical Temporal Shipping database; and

2) http://oai.dtic.mil/oai/oai?&verb=getRecord&metadataPrefix=html&identifier=ADB037108

For discussion of some strengths and weaknesses of such databases for informing noise predictions see:

- *Heitmeyer, R. M., S. C. Wales, and L. A. Pflug. 2004. Shipping noise predictions: capabilities and limitations. Marine Technology Society 37, 54-65.*

This participant further noted that these models vary in the degree to which they reflect differences among ship or propulsion types or operating conditions such as speed. A model that incorporates ship data has recently been developed for a heavily trafficked and biologically-sensitive marine region off the coast of the United States to evaluate the changes in predicted noise associated with different management options.

According to this participant, all such predictions based on models are faced with the same questions: what resolution in accuracy is required for the management question and what resolution of input data is required to provide such accuracy? Based on the factors impacting large-scale variation in ambient noise, most predictive models operating on large scales and over long time periods are likely, if they are doing well, to be ±5-10 dB re 1 uPa at any one place or point in space or time. The challenge will be to specifically tie ship volume to ambient noise, especially the contribution of distant shipping noise (difficulties of tying point source with non-point source issue).

Finally with regard to this issue, this participant noted that similarly, current knowledge indicates that a static noise threshold for chronic exposure to underwater noise for all marine species, all behavioral states and in all habitat types is unlikely to be scientifically supported. Thus, we need to continue to increase the accuracy of both predictive shipping noise models (particularly in biologically sensitive areas with heavy vessel traffic) and knowledge of species responses to different levels of noise. Generally, though there is not a single threshold among animals for noise impacts. Impacts fall along a continuum depending on what impact one is concerned with (e.g., injury, masking, hearing impairment, behavioral responses). Thus, because of this, assigning a single number is often difficult.

2. Measurement and classification of ship noise levels. The second piece of work that is worth considering is to increase the database of ship noise records that contain information about the vessel (speed, size etc.). This would tell us how the noise levels vary with ship size, speed etc. This can be done if two simultaneous data sets are available - the noise recordings and the characteristics of the vessel making that noise. Most historical noise data sets do not include the latter, but the introduction of AIS could change this. If the AIS data can be recorded at the same time as the noise data, then with some noise propagation modeling to allow for noise attenuation over distance, the noise recordings can be linked to the noise at the vessel for its given speed and size.

    - In response to this comment, one participant passed on the reference to Hatch et al 2008 for such a study. A similar study (linking passive acoustic array data to AIS records) is being completed off the coast of Southern California. It was noted that this is a level of resolution on the per-ship basis that was not the focus of the Hatch et al. study but is certainly possible and may provide an option for evaluating some detailed aspects of shipping noise outside of model basin or Naval test facilities. Also it could provide methods for monitoring post guidelines introduction/implementation.

It was also noted that if the ship operator is willing to provide additional data it might be possible to also link it to prop blade loading etc. There are two types of noise recorder deployment configurations that could be used to generate this information:

a) In locations of light shipping, with only one vessel in range at a time, then just a single noise recorder will provide a one-on-one connection between the noise and the vessel. One participant noted that the distance between the noise source (ship) and the hydrophone and the acoustic profile of the water column must also be recorded; otherwise, the data may not be meaningful.

   - In response to this comment, one participant stated that this is also possible in areas of moderate-heavy shipping, with a dense enough array of hydrophones or a close enough recording proximity to the vessel of interest (involves filtering background noise to determine single vessel noise profile).

b) For locations where there are several ships in range at once, the location of the noise source has to be known in order to link it to the specific ship. This requires an array of noise recorders to be deployed in order to get a fix on the source. It was noted that several such arrays exist in the Indian, South Pacific and South Atlantic oceans (one is off the coast of Western Australia). These were installed as part of the Comprehensive Test Ban Treaty Organization measurement program. These arrays would be well suited to determining vessel-specific ship noise if linked with AIS or similar information.

   - One participant noted in response to this point that it can be argued that the much higher density of shipping in the Northern hemisphere, bottom-mounted hydrophone arrays (decommissioned or otherwise) would provide a rich source of data to be pursued. That said, although some of these data have been declassified for biological studies (http://www.dosits.org/gallery/tech/pt/sosus1.htm), much of the information (particularly regarding the spatial relationships among recording nodes, dimensions that are central to accurate localization of sources) remains limited in its general accessibility. As indicated, this is not likely to be a timely source of data. It is also important to note: the only good forecasting model will have to apply an "average" noise profile to individual ships tracked through AIS and LRIT and then predict what the collective contribution of ships over near and distant ranges. Furthermore, there remains a question as to whether noise has to be tied to a specific ship. Perhaps the Correspondence Group should be focus more broadly and work on solutions based on certain basic vessel categories or operating conditions.
   - One participant stated that these ideas are sound but again raise the question of resolution, one that is now being faced by several standard committees focusing on measurements for underwater noise from ships: how much accuracy is needed to address the management question, how should measurements be conducted to ensure that level of accuracy, and how can we ensure that standardized and thus comparable measurements are made?

4b Another participant opined that the 50 Hz maximum in the background noise spectra, which can be considered as a total of many ships, seems to be the main obstacle to substantially reduce noise in the ocean. This 50 Hz maximum occurs in many ships but not in all. It is supposed that this phenomenon is related to propeller cavitation. However, the detailed cause of this phenomenon is not well known as it has not been of interest from other considerations so far.

Note: There was a discussion between two participants regarding this 50 Hz component. One participant questioned whether it referred to a narrowband or broadband source. If narrowband, then it was noted that all ships have an auxiliary power supply frequency of 50 Hz or 60 Hz and for many years 50 Hz was predominant. Even for broadband, it might be an enhancement of the auxiliary frequency resulting in the 50 Hz predominance.

The originator of the comment responded that the 50 Hz component is broad band, although it was noted that the mains frequency today is generally 60 Hz. This participant did not know of a measurement where a 60 Hz or 120 Hz tonal appears in an underwater radiated noise spectrum at an equivalent level. After all, it is very unlikely that a 50/60 Hz mains frequency component is effectively radiated via the ship's structure into the water, and a narrowband mechanical structural vibration of this frequency and magnitude able to generate sufficient underwater noise has not been reported to their knowledge. It was therefore recommended to avoid a discussion of this type of noise sources.

Another participant noted that it's important to study the effects of noise reduction techniques/strategies on different parts of the frequency spectrum in order to be most effective, efficient, and targeted with our quieting approaches. It was felt that the impact of noise must be known to determine the most important noise sources.

As opposed to this, the noise reduction of medium speed engines can be addressed with existing technology with an expected good effect.

It was thought by one participant that if medium speed diesels are treated in an appropriate way, further reduction might be limited by the contribution of the low speed engines. Their underwater noise contribution is not well known because it is masked by propeller and medium speed diesel noise. Structure-borne noise measurements, however, show that they may limit substantial reduction of overall noise. This also requires research. Noise reduction measures are very limited as of the size of these engines (hundreds to thousands of tons).

In going into more detail, this participant felt that the main needs for action are emphasized as follows:

1. The cause of the 50 Hz noise contribution must be revealed and a solution for the reduction of this level should be found. It should be noted that another participant stated that it seemed that it had been agreed that the Group not pursue the 50 Hz predominance. This will be an issue that will have to be resolved by the Group as it moves forward.

2. Investigations into propeller-induced radiated noise of commercial vessels should be extended and supported by further research.

3. Further investigation is needed to provide sufficient evidence for ship type dependency of underwater noise characteristics to have a better indication for potential countermeasures.

4. It is still a major concern to develop/describe a verification method to prove a successful reduction of underwater noise radiation, especially for ships in service after retrofitting.

5. The noise effects of geared medium speed propulsion systems with power-take-off (constant shaft speed) and controllable pitch propeller shall be investigated for all operating conditions (particular case).

It was emphasized that researchers contributing to the IMO Noise Reduction Team should discuss in their national facilities whether relevant observations regarding the above research needs have been made, e.g., whether these may have been a by-product of other research topics.

4c Another participant noted that the measurement must be done to a standard as radiated noise from a single source is subject to inverse square law; that is, the dB level reduces rapidly with range. This links with the above in the sense that the overall contribution to the fleet to ambient noise levels is not simply a summation of radiated noise from all ships.

One participant agreed with need for standardization of measurement. Currently there is an Acoustical Society of America Working Group (WG 47) trying to write standards (Look under ASC 12 Noise: http://www.acosoc.org/standards/).

It was also noted by another participant that there is some confusion about the point regarding radiated noise. If the initial comment is saying that the received levels have to be taken into account—rather than source levels of ships in various locations from the receiver--then yes that's true. But, according to the participant responding to the initial comment, this is not done.

- *ISO FOCUS Article: TC8* One participant endorsed the statements in this article, "[i]n order to control and regulate noise emission from vessels, it is important to have clear and consistent measuring methods…" and "[a]lthough consultants and others have carried out underwater noise measurements from various types of underwater equipment and vessels, the lack of standards limits any comparison of measurements."

Another participant fully supported the statement that it is necessary to have a set of agreed standards for measuring and reporting ship noise levels. It was noted as fundamental to the success of any noise quieting activity that a comprehensive noise signature database be available to all areas of the community to all the work to continue.

It was further noted that cavitation is the dominant far field effect; however, this is one of the areas that will improve as GHG reduction technology starts to take an even greater effect.

This participant also expressed concern about the attribution of noise level to harmful effect and that further information is warranted on this issue.

- One participant was not clear about this comment and asked whether we are assuming here that the original comment pertained to further structural streamlining, propeller modifications, additional engine/propulsion types and efficiency measures to address fuel costs and GHG emissions that would also reduce noise.

One participant noted that the Group to date is only addressing the minimization of the introduction of incidental noise into the marine environment from commercial shipping and has not yet given consideration to the level of reduction in the potential to adversely affect marine receptors. It was noted that we have yet to have a clear agreed "just enough" statement of what frequency ranges should be of concern and addressed in the guidelines. This participant was concerned that the Correspondence Group is operating on the assumption that the frequency range at issue is limited only to the low frequency end of the spectrum and opined that no all marine receptors of interest and concern are susceptible to the adverse impacts at the lower end of the spectrum.

4d One participant stated that while of course ships are noisy in certain frequency ranges, there are levels at which they do not raise natural background noise levels unless the ship is in close proximity (i.e. less than 10 km away). It may therefore be worthwhile to address this issue specifically. It was also noted by this participant that the Correspondence Group has collected a number of measures or technologies which may have an effect on acoustics. It was suggested that it may be worthwhile to address these one by one and demonstrate their fields of application, their operational envelope, their technical status, and their potential future relevance.

4e One participant noted that we have quite a bit of information in front of us already in the reports and recommendations that should be discussed more deeply to try to arrive at quickly achievable recommendations that will have a good impact. It was suggested that there is a lot of good information in these reports from various meetings and symposia that should be further discussed. This participant also noted we must keep in mind any adverse impacts, especially given the state of the global economy.

4f One participant noted that the guidelines produced should be based on strong evidence. The documents that have been circulated to the Group help provide this basis as well as ongoing research, such as that proposed by the IFAW research project. While this amalgamated set of responses received from members of the Correspondence Group help expand the evidence base, there is no substitute for evidence that is peer reviewed and agreed for use by the Group. This participant noted that this set of responses may contain data/information which is not supported by good evidence/engineering and as such must be given an appropriate weighting when being considered. (Note by Chair: Obviously, all efforts will be made to ascertain these issues and correct them as the work of the Group progresses.)

4g It was further noted by a participant that environmental conditions will increase/decrease the propagation of ship noise depending on its frequency. This constraint will have to be considered when determining the efficacy of a particular quieting capability. Factors such as layer depth, natural background noise levels due to sea state or precipitation and depth of water will constrain or enhance the propagation of certain frequencies. There are ambient noise models available to the community, most of which have their origin in military work. A number of Strategic Environmental Assessments for UK waters contain information from forecast ambient noise models.

4h One participant opined that the most urgent need to do something seems to be related to the frequency range where shipping noise prevails over primordial background noise levels (10 to 300 Hz). These levels are dominated by cavitation and machinery noise from diesel engines, mainly from conventionally propelled cargo ships. It was therefore suggested that we concentrate on these kinds of ships and:

a. find the underlying mechanism which creates the prominent 50 Hz hump in almost all distant shipping spectra;

b. investigate low frequency propeller noise due to cavitation;

c. finds the noise contribution of diesel engines which today are partly masked by propeller noise;

d. describe the noise characteristics of ship types (container, tanker, bulker, general cargo, RoRo, other), according to an acoustic classification to be determined; and

e. estimate the effect of known abatement technologies (e.g., propeller design, resilient foundations).

Additional Literature Cited (not yet distributed to Correspondence Group), including papers cited in MEPC papers:

Cato, D.H., and R.D. McCauley. 2002. Australian research in ambient sea noise. Acoustics Australia April:1-13.

Clark, C.W. 1999. On the subject of potential impact of human-made noise on whales. Journal of Cetacean Research and Management 1:207-209.

Heitmeyer, R.M., S.C. Wales, and L.A. Pflug. 2004. Shipping noise predictions: Capabilities and limitations. Marine Technology Society Journal 37:54-65.

National Research Council (NRC). (1994). *Low-frequency sound and marine mammals: Current knowledge and research needs.* Washington, DC: The National Academies Press.

National Research Council (NRC). (2000). *Marine mammals and low-frequency sound*. Washington, DC: The National Academies Press.

National Research Council (NRC). (2003). *Ocean noise and marine mammals*. Washington, DC: The National

Norwood, C. (no date). Noise from vessels and its control. Teaching materials, Defense Science and Technology Organization, Australia.

Richardson, W.J., C.R. Greene jr., C.I. Malme, and D.H. Thompson. 1995. Marine Mammals and Noise. San Diego, California: Academic Press.

Southall, B. L., A. E. Bowles, W. T. Ellison, J. J. Finneran, R. L. Gentry, C. R. Greene Jr., D. Kastak, D. R. Ketten, J. H. Miller, P. E. Nachtigall, W. J. Richardson, J. A. Thomas, and P. L. Tyack. (2007). Marine mammal noise exposure criteria: Initial scientific recommendations. Aquat. Mamm. 33, 411-521.

***

ANNEX 2

DOCUMENTS CIRCULATED TO THE CORRESPONDENCE GROUP FOR BACKGROUND INFORMATION

1 MEPC documents: MEPC 58/19, MEPC 58/INF.19, MEPC 57/INF.4, MEPC 57/INF.22.

2 Other IMO documents: IMO Resolution A.468(XII) Code on Noise Levels Onboard Ships (some of this document may not be pertinent to our issue, but we are including it because it is from IMO and on a similar issue) and MSC./Circ.1014.

3 International Workshop on Shipping Noise and Marine Mammals, Held by Okeanos-Foundation for the Sea, Hamburg, Germany (21st -24th April 2008).

4 Andrew, Rex K, Bruce M Howe, James A Mercer, and Matthew A Dzieciuch 2002. Ocean ambient sound: Comparing the 1960s with the 1990s for a receiver off the California Coast. Acoustic Research Letters Online [DOI 10.1121/1.1461915].

5 Hatch, L, C Clark, R Merrick, S Van Parijs, D Ponirakis, K Schwehr, M Thompson, and D Wiley 2008. Chracterizing the relative contributions of large vessels to total noise fields: A case study using the Gerry E. Studds Stellwagen Bank National Marine Sanctuary. Environmental Management 42: 735-752.

6 Payne, Roger and Douglas Webb 1971. Orientation by Means of Long Range Acoustic Signaling in Baleen Whales. Annals of the New York Academy of Sciences, 188 (1): 110-141.

7 Southall, BL, RJ Schusterman, and D Kastak 2000. Masking in three pinnipeds: Underwater, low-frequency critical ratios. J. Acoust. Soc. Am 108 (3): 1322-1326.

8 Southall, BL 2005. Final report of the NOAA International Symposium: "Shipping Noise and Marine Mammals: A Forum for Science, Management, and Technology," 18-19 May, 2004, Arlington, VA, U.S.A.

9 Southall, BL and A. Scholik-Schlomer. 2008. Final report of the NOAA International Conference: "Potential Application of Vessel-Quieting Technology on Large Commercial Vessels," 1-2 May, 2007, Silver Spring, MD, U.S.A.

10 Southall, B. L., A. E. Bowles, W. T. Ellison, J. J. Finneran, R. L. Gentry, C. R. Greene Jr., D. Kastak, D. R. Ketten, J. H. Miller, P. E. Nachtigall, W. J. Richardson, J. A. Thomas, and P. L. Tyack. (2007). Marine mammal noise exposure criteria: Initial scientific recommendations. Aquatic Mammals 33, 411-521.

11 Resolution No. 4, Adverse Effects of Sound, Vessels and Other Forms of Disturbance on Small Cetaceans, 5th MEETING OF THE PARTIES TO ASCOBANS, 18 - 20 September and 12 December 2006, The Netherlands

12 Roussel E. 2002. Disturbance to Mediterranean cetaceans caused by noise. In: G. Notarbartolo di Sciara (Ed.), Cetaceans of the Mediterranean and Black Seas: state of knowledge and conservation strategies. A report to the ACCOBAMS Secretariat, Monaco, February 2002. Section 13, 18 p.

13 Piersall, Capt Charles H., Chair ISO/TC 8, Ships and marine technology, ISO Focus January 2009, When silence means survival – Protecting the marine ecosystem from underwater irradiated noise.

___