# Convention on the Conservation of Migratory Species of Wild Animals

CMS

*Secretariat provided by the United Nations Environment Programme*

UNEP


## 16TH MEETING OF THE CMS SCIENTIFIC COUNCIL

*Bonn, Germany, 28-30 June 2010*


UNEP/CMS/ScC16/Inf.12.1
Agenda Item 13.3c


**CALL FOR INFORMATION IN FOLLOW-UP OF CMS RESOLUTION 9.19 ON OCEAN NOISE IMPACTS**

*(Response received from the International Maritime Organization)*

**International Maritime Organization's work on "Noise from commercial shipping and its adverse impacts on marine life"**

In October 2008, the Marine Environment Protection Committee (MEPC) at its fifty-eighth session (MEPC 58), having considered a proposal by the United States (MEPC 58/19) on minimizing the introduction of incidental noise from commercial shipping operations into the marine environment to reduce potential adverse impacts on marine life, approved the inclusion of a new item in the agenda on "Noise from commercial shipping and its adverse impacts on marine life" with a target completion date of three or four sessions. MEPC 58 also established an intersessional Correspondence Group, co-ordinated by the United States, to 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 it was instructed to develop voluntary technical guidelines for ship-quieting technologies as well as potential navigation and operational practices.

In July 2009, MEPC 59 considered the First report of the Correspondence Group (MEPC 59/19) and re-established the Correspondence Group, with instructions to continue its work along the lines agreed at MEPC 59 and report to MEPC 60.

In March 2010, MEPC considered the Second Report of the Correspondence Group (MEPC 60/18) and noted that the work conducted during the intersessional period had focused on technological issues which are set out in annex 1 (cavitation, machinery and hulls) and annex 2 (dominant frequency and IMO-related issues) of the said report. Other aspects of incidental underwater noise generated from shipping would be retained for future reference. The Committee also noted that the work on standards for underwater noise was contained in annex 3 and that research needs were contained in annex 4 to document MEPC 60/18.

With regard to the issue of a regulatory framework, MEPC noted that there were other entities working on regional legislation for various types of noise. Given that the Correspondence Group's terms of reference were confined to the work on non-mandatory technical guidelines for ship-quieting technologies as well as potential navigation and operational practices, no further work had been conducted on this matter. The Committee also noted that there was general support for the current direction of the work being undertaken by the Correspondence Group.

The Committee agreed that the Correspondence Group should concentrate its efforts on the major element of cavitation as this would lead to other efficiencies, consequential fuel savings and reduction of emissions. The Committee also encouraged that research on the issue of underwater noise should be conducted simultaneously with the work of the Correspondence Group.

The Committee, with a view to progressing the matter further, agreed to re-establish the Correspondence Group, under the leadership of the United States*, and instructed it to:

.1 continue its work along the lines of the terms of reference approved by MEPC 58, taking into account comments and other input received at and after MEPC 60; and

.2 submit a further report to MEPC 61.

Note that MEPC 61 will be held at IMO Headquarters from 27 September to 1 October 2010.

---

* **Coordinator:**
Ms. Trisha Bergmann
NOAA Office of International Affairs
TEL: 202-482-2652
e-mail: Trisha.Bergmann@noaa.gov

INTERNATIONAL MARITIME ORGANIZATION

IMO

E

MARINE ENVIRONMENT PROTECTION COMMITTEE
58th session
Agenda item 19

MEPC 58/19
25 June 2008
Original: ENGLISH

# WORK PROGRAMME OF THE COMMITTEE AND SUBSIDIARY BODIES

## Minimizing the introduction of incidental noise from commercial shipping operations into the marine environment to reduce potential adverse impacts on marine life

**Submitted by the United States**

**SUMMARY**

| | |
|---|---|
| ***Executive summary:*** | This document proposes the inclusion of a new high priority work programme item on the agenda of the Committee to take action to minimize the incidental introduction of noise from commercial shipping operations into the marine environment to reduce potential adverse impacts on marine life. A significant and growing portion of human noise input to the ocean is attributable to the increasing number and size of commercial ships operating over wide-ranging geographic areas. Noise from such ships has the potential to disturb behaviour and interfere with critical life functions of marine animals. Given the global nature of shipping, the long lifespan of a ship, and that the Organization is the recognized entity for the consideration of issues pertaining to international shipping, it is essential that the Organization provide the forum for the comprehensive consideration of global strategies to address this issue. |
| ***Strategic direction:*** | 1, 7 and 13 |
| ***High-level action:*** | 1.1.2 |
| ***Planned output:*** | 1.1.2.3 |
| ***Action to be taken:*** | Paragraph 8 |
| ***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 57/INF.4 and MEPC 57/INF.22 |

## Introduction

1 The United States proposes the addition of a new high priority work item to the agenda of the Marine Environment Protection Committee (MEPC). This work item is to 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 through the development of non-mandatory technical guidelines for ship-quieting technologies as well as potential navigation and operational practices. This proposal, attached as annex 1 to this document, is in accordance with MSC-MEPC.1/Circ.1 (15 December 2006), which sets forth the criteria for submitting a new work item proposal.

## Background

2 The introduction of human-produced noise[1] into the marine environment and its potential adverse impacts on marine life is a matter of increasing concern. While repeated measurements in an area over time to determine trends are limited, levels of background sound in the ocean (or "ambient noise") are known to be increasing in certain areas and within specific sound frequency ("pitch") bands. A significant human contribution to overall ambient noise at low frequencies is thought to be generated by the growing use of the ocean for international shipping. Commercial ships, which are increasing in both number and size, are producing ever-greater amounts of underwater noise as an incidental by-product of operation[2] (Southall 2005). In fact, multiple studies estimate, based on recent studies off the California coast, that there has been approximately a 3 decibel (dB) increase in − or a doubling[3] of − background noise from commercial shipping per decade in some ocean areas. (Andrew *et al.* 2002, Cato and McCauley 2002, McDonald *et al*. 2006, Andrew *et al.* in press). Additionally, many other studies have characterized the relative contributions of shipping to the total low frequency noise in highly-trafficked and less-trafficked coastal and open-ocean areas. These studies indicate that ships are the dominant source of low frequency noise in many, if not most, highly-trafficked coastal zones in the northern hemisphere. These areas are also heavily used by marine animals that depend on sound, many of which use the same low frequency bands that are being affected by incidental noise from commercial shipping (Cato 1976, Ross 1976, Worley and Walker 1982, Zakarauskas 1986, Bachman *et al*. 1996, Zakarauskas *et al*. 1990, Curtis *et al.* 1999, Andrew *et al*. 2002, Cato and McCauley 2002, Heitmeyer *et al*. 2004, McDonald *et al*. 2006, Andrew *et al*. 2008, Hatch *et al*. in press).

3 Most marine animals produce and receive sounds for critical life functions such as communicating, foraging, evading predators, and navigating. Much as human rely heavily on their vision for most activities, most marine animals rely on sound for survival and reproduction. Scientific investigations of many marine animals (including mammals, fish, and even some invertebrates) have shown that the production and reception of sounds are critical to various aspects of their life histories. Human-produced sound has the potential to interfere with various

1 "Noise" is the term to describe unwanted sound, whereas "signals" are sound with some biological importance. The generic term "sound" is used where the intent is not to distinguish between noise and signals or where the utility or effect is ambiguous or unknown; "noise" is used to refer specifically to exposures with adverse effects or in specific technical terms such as "ambient noise" (the general background din) or "masking noise" where interfering sound is by definition "noise."

2 Incidental in this context means the unintended production of sound energy from the propulsion systems and internal machinery of vessels. It does not include active depth finders and other communication sources used in orientation and safety of navigation.

3 In sound level terms, a doubling in the power of sound is measured as 3 dB.

important biological functions of marine animals. The range of resulting adverse impacts is highly dependent on characteristics of the sound source, the environment where the sound occurs, and the animals receiving the sounds. Marine animals such as large whales, many fish, and some seals and sea lions are particularly vulnerable to adverse impacts from incidental shipping noise because they primarily use the same low frequency sounds as that generated by commercial ships for such things as communication and/or to perceive their environments.

4 Among multiple human-induced sources of low frequency sound in the marine environment, commercial ships represent significant and relatively loud individual sources of sound, the exact characteristics of which depend on ship type, size, mode of propulsion, operational characteristics, speed, and other factors. Much – and in some conditions most – of the incidental noise generated by large ships results from propeller cavitation. Onboard machinery and turbulence around the ship's hull also generate incidental noise that can be transmitted underwater via direct or secondary paths. Various parts of ships produce different frequency sounds which propagate differently in the water, with low frequency sound generally travelling farther due to the physical properties of sound in water. Low frequency sounds from ships can travel hundreds to thousands of miles and thus can increase ambient noise levels in large areas of the ocean. This has the very real probability of interfering with the abilities of marine animals to hear and communicate in the same frequency ranges (see paragraph 3), in some cases over relatively large areas. In general, however, the loudest areas are expected to be where the highest ship traffic occurs. While individual ships represent point sources for noise, and efforts directed at quieting will likely be approached on a ship-by-ship basis, the primary concern in terms of adverse impacts on marine life is likely to be the overall contribution of many vessels to increasing ambient noise levels, particularly in coastal areas where marine life is relatively abundant. It is important to recognize that radiated sound, unlike persistent forms of pollution such as heavy metals or greenhouse gases, once reduced or eliminated does not linger in the environment. Thus, the application of strategies to quiet vessels, including in particular quieting technologies, has the potential to reap immediate benefits for marine life.

5 In addition to the probable tangible benefits to marine life from quieting commercial ships, there are other considerations that support the addition of this work item to the Committee's agenda. First, while the Organization is currently considering the revision of its Code on Noise Levels On Board Ships (A.468(XII) (November 1981)) which addresses the adverse impact of noise on the crew and passengers[4] and it has adopted MSC/Circ.1014 (12 June 2001) which recognizes that mariner stress and fatigue may be caused by noise on board ships, any additional strategies taken to address sources of underwater noise from commercial ships could also benefit the crew and any passengers on board such vessels. Second, sound produced as an incidental by-product of a vessel's operation serves no particular function in the transportation of goods and may, to some extent, represent wasted energy. Although the underlying technical issues involved are highly complex and need further consideration and validation, the potential for increased shipboard efficiency as a result of the reduction of incidentally-generated shipboard noises should be explored. These potential benefits may offset costs associated with the implementation of ship-quieting technologies. Third, over the next several years, various requirements set forth in International Maritime Organization (IMO) instruments will enter into force. These requirements may result in ships being replaced by new ones (*e.g.*, single hull tankers by double hull tankers) or new equipment being developed to address specific issues (*e.g.,* MARPOL Annex VI requirements). If the reduction of noise is taken into account in the building of new ships or the development of new equipment, significant noise reductions could take place. Consideration of this issue at the design phase of a ship and its

[4] MSC 83/28, paragraph 25.41.

equipment is more cost-effective, efficient, and practical than retrofitting a vessel or affecting where a ship operates or its operational practices.

**Proposal**

6 Based on the above considerations, the United States invites the Committee to add to its agenda, as a high-priority work item, the development of non-mandatory technical guidelines for commercial ship-quieting technologies as well as potential navigational and operational practices, to minimize the introduction of incidental noise from commercial shipping operations into the marine environment to reduce potential adverse impacts on marine life.

7 To accomplish this task, the United States proposes that a correspondence group be formed to work on this issue. If the Committee agrees with this proposal, potential terms of reference for the establishment of the Correspondence Group could include:

.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.

The references and other literature considered in the development of this submission are set forth in annex 2.

**Action requested of the Committee**

8 The Committee is invited to add to its agenda, as a high-priority work item, minimizing the introduction of incidental noise from commercial shipping operations into the marine environment to reduce potential adverse impacts on marine life and form a correspondence group to work on this issue.

***

## ANNEX 1

## CRITERIA FOR NEW WORK PROGRAMME ITEMS

### Scope of the proposal

1 As a new work item, the Committee would be able to consider minimizing the introduction of incidental noise from commercial shipping operations to reduce potential adverse impacts on marine life, with an emphasis on practical, effective solutions that can be implemented by the shipping industry. The Committee is invited in particular to develop non-mandatory technical guidelines on potential design and construction technologies and on potential navigation and operational practices that may minimize incidental noise from commercial shipping.

### Need for work programme item

2 The criteria for a new work programme item require that a need be documented and, for proposals requesting the development of a new convention or amendment of an existing convention, a compelling need must be shown. The proposed action here is not a request for the development of a new convention or an amendment to an existing convention and therefore this proposal does not have to meet the burden of showing a compelling need. Notwithstanding, the United States believes that there exists a compelling and urgent need for the Committee to add this item to its agenda because of potential adverse impacts on the marine environment and marine life as well as on the crew and any passengers on board ships. There are also potential economic benefits that may be obtained by addressing this issue.

*Environmental Impacts*

3 Noise exposure may pose a host of potential adverse impacts to marine animals, including in particular marine mammals (*e.g.*, whales, dolphins, porpoises, seals, sea lions) and fish. Natural or human-generated noise can have various adverse effects on animals, including: alteration of behaviour; reduction of communication ranges for social interactions, foraging, and predator avoidance; temporary or permanent compromise of the auditory or other systems; and/or, in extreme cases, habitat avoidance or even death (Richardson *et al*., 1995; Southall *et al*., 2007). Potentially widespread impacts, particularly related to communication interference or "masking," may result from increasing background ambient noise levels due to human activities. With regard to the incidental noise generated by shipping, the general low frequency band of large vessel noise overlaps the frequencies generally produced by some marine animals, primarily large whales, seals and sea lions, and fish (see Figure 1 below). Additionally, concerns with regard to such noise and its potential adverse impacts on acoustically-oriented marine animals is of increasing concern because: (1) commercial shipping operations cover a wide geographic area, (2) low frequency sounds from ships travel great distances, and (3) since international shipping is continuous, incidental noise from ships is ever-prevalent.

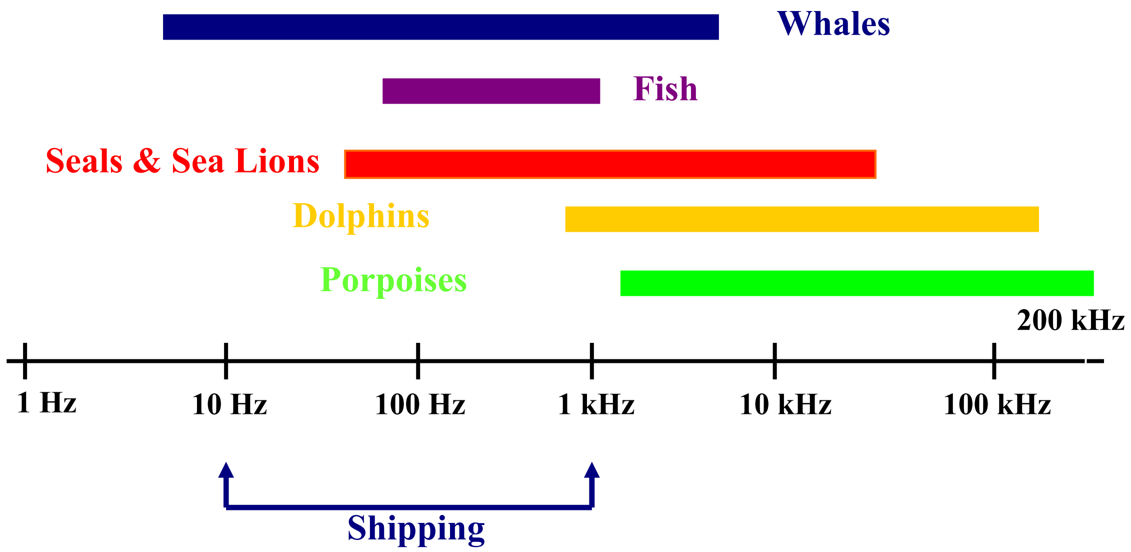



**Figure 1:** **Frequency relationships between marine animal sounds and incidental noise from commercial shipping**

4 The primary concern regarding potential adverse impacts of incidental shipping noise is not related to acute exposures, but rather to the general increase in continuous background ambient noise that may result from concentrations of vessel operations and the potential masking of marine animals' communication systems. While there is insufficient longitudinal data to conclude that ambient noise levels are increasing in large areas of the ocean as a function of vessel sounds, several recent studies off California analysing measurements over several decades do indicate changes that suggest, for particular areas, there has been approximately a 3 decibel (dB) increase in – or a doubling[5] of – background noise from commercial shipping noise per decade (Andrew *et al.*, 2002; McDonald *et al.*, 2006; Andrew *et al.* in press; see Figure 2 below). Because of the logarithmic nature of sound and what is known about hearing systems in mammals, seemingly small changes in background noise levels can result in large reductions of marine animals' communication ranges (see Figure 3 below).

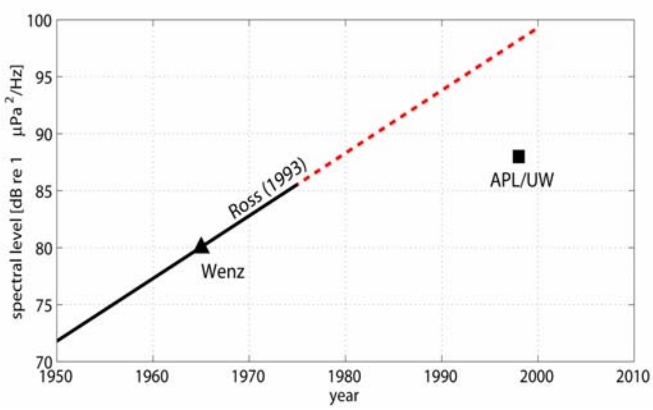



**Figure 2:** **Ambient noise measurements in the 100-200 hertz (Hz) band measured off California in the 1950s (Wenz, 1962; Ross, 1993) and Applied Physics Laboratory/University of Washington (APL/UW) noise measurements in the late 1990s (Andrew *et al.*, 2002)**

5 In sound level terms, a doubling in the power of sound is measured as 3 dB.

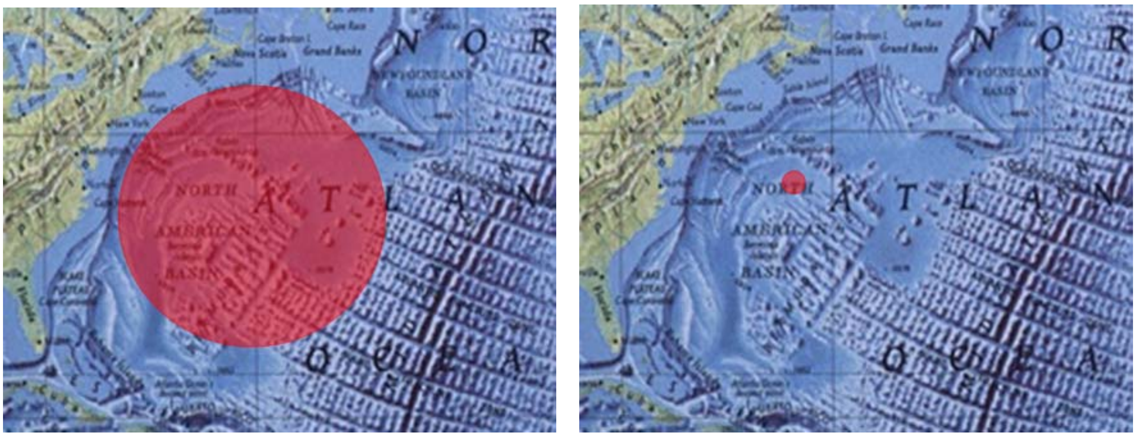


**Figure 3: Expected reductions in blue whale communication ranges from the many hundreds of square miles possible prior to the advent of commercial shipping and other industrialized sounds (left) compared to the greatly reduced possible ranges for those same voices today (right). Figure courtesy of Christopher Clark, Cornell University based on historical and recent low frequency ambient noise and whale call measurements**

5 There has been extensive documentation of how sound can mask marine animals' communication systems, including several specific examples relating to commercial shipping noise and its potential adverse impacts on marine life.

.1 The fact that noise masks hearing is well established for human beings (*e.g.*, Fletcher, 1940) and other animals, and it appears to be quite similar as a general phenomenon across many mammalian species (see Fay, 1986; Ward, 1997). Numerous studies have examined the impacts that masking has on a variety of species, and have considered and/or quantified the extent to which low frequency noise from shipping can dramatically reduce communication ranges for marine animals (*e.g.*, Payne and Webb, 1971; Erbe and Farmer, 1998, 2000; Southall *et al.*, 2000, 2007; Erbe 2002; Morisaka *et al.*, 2005, Nowacek *et al.*, 2007).

.2 Recent data on blue whales (*Balaenoptera musculus*) and North Atlantic right whales (*Eubalaena glacialis*) indicate that these species may be adjusting their vocalization (frequency and loudness) on both short and long timescales to compensate for masking associated with vessel noise (McDonald *et al.*, 2006; Parks 2003).

.3 Measurements using a sophisticated underwater listening array demonstrated that a Cuvier's beaked whale (*Ziphius carvirostris*) reduced the production of sounds associated with foraging in response to a passing cargo ship (Soto *et al.*, 2006).

*Human beings*

6 IMO has recognized that noise levels on board ships affect human beings and has adopted a Code to address this issue (Code on Noise Levels On Board Ships, A.486(XII)) (November 1981). In recognizing the importance of this issue, the Maritime Safety Committee

recently assigned consideration of the revision of this Code to the Design and Equipment Sub-Committee. This Code gives guidance on, and recognizes that there should be, maximum noise levels and exposure limits. It focuses on prevention of potentially hazardous noise levels on board ships and reduction in the exposure of the crew and passengers to noise so as to, *inter alia*, prevent hearing loss and provide safe working conditions, taking into account the need for speech communication, hearing audible alarms, and working in an environment where clear-headed decisions are necessary to ensure safety of navigation and other essential operations of the ship. Circular 1014 adopted by the Maritime Safety Committee on 12 June 2001 also recognizes that noise may have an adverse impact on mariners by causing stress and fatigue. Adoption of strategies that quiet commercial ships for the benefit of marine life may also yield benefits for mariners and any passenger on board commercial ships.

*Economic Benefits*

7 As noted above in the background section, sound produced as an incidental by-product of vessel operations serves no particular function and may, to some extent, represent wasted energy. Although the underlying technical issues involved are highly complex and need further consideration and validation, quieter vessels may be more efficient to operate and maintain. Thus a reduction in noise may represent a reduction in both propeller cavitation and ship-board vibration and, consequently, result in reduced operational, maintenance, and fuel costs. There may be economic benefits to be gained by the shipping industry by minimizing the introduction of incidental noise into the marine environment. Additionally, it is also important, cost-effective, and practical to consider noise reduction technologies and strategies as part of the design phase of a ship and its equipment or in the shipbuilding contract instead of attempting to address it on existing ships or by affecting where a ship operates or its operational practices.

**Is the issue within the scope of IMO's objectives and Strategic Plan of the Organization?**

8 The addition of this issue to the Committee's work programme falls squarely within the scope of IMO's objectives and Strategic Plan. Resolution A.900(21) sets forth the objectives for the Organization in the 2000s. By addressing and minimizing the introduction of incidental noise into the marine environment from commercial shipping operations to reduce potential adverse impacts on marine life, the Committee would fulfil several of the objectives identified in the resolution. First, the resolution directs the Committees to take measures to implement a proactive policy so that trends which might adversely affect the safety of ships and those on board and/or the marine environment are identified at the earliest feasible stage and action taken to avoid or mitigate such effects. Second, it directs the Committees to shift emphasis on to people and address safety and environmental protection issues by ship types. The relevant objectives and Strategic Plan elements are addressed individually below.

*Objective: Implementation of a proactive policy to address trends which might adversely affect the marine environment and identification of such trends at the earliest feasible stage so avoidance or mitigation action may be taken*

9 There is increasing recognition of the introduction of noise into the marine environment and its potential adverse impacts on marine life. Various international organizations are taking action to address it. The United Nations General Assembly in A/Res/62/215, paragraph 120, recognizes the potential adverse impact of ocean noise on marine living resources and encourages further studies and consideration of this issue. Three regional organizations have also taken action. The parties to the Convention on Migratory Species (*e.g.*, the Agreement on the

Conservation of Cetaceans of the Black Sea, Mediterranean Sea and Contiguous Area (ACCOBAMS) and to the Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas (ASCOBANS)) have adopted resolutions and commissioned research on the effects of noise on marine mammals. *See* ASCOBANS MOP 4, Resolution 5, Effects of Noise and of Vessels (2003). In 2006, a report on Marine Acoustics and the Southern Ocean by the Scientific Committee on Antarctic Research was submitted to the Antarctic Treaty Consultative Meeting. ACTM XXIX, WP 41. Noise from shipping was explicitly considered in this report.

10 As there is sufficient data that the introduction of incidental noise from commercial shipping is an important and increasing source of sound in the marine environment and there are documented concerns regarding its potential adverse impacts on marine life, it is clearly part of a trend that may adversely affect the marine environment. Therefore, consistent with the Organization's objectives in resolution A.900(21), the Committee should – by adding this issue to its work agenda – take proactive action now to address it by taking action to minimize and reduce the adverse effects of the introduction of incidental noise from commercial shipping operations into the marine environment.

*Objective: There should be a shift in emphasis to people and addressing environmental protection issues by ship types*

11 By adding this issue to its work agenda, the Committee is fulfilling the objective of emphasizing people and addressing this environmental protection issue by ship type. First, as noted above in paragraph 10, the adoption of strategies to minimize the introduction of incidental noise by commercial shipping into the marine environment may also yield benefits to mariners and any passenger on board commercial ships. Second, with regard to considering environmental protection issues by ship type, each ship produces different incidental noise. The exact characteristics of this noise depend on ship type, size, mode of propulsion, operational characteristics, speed, and other factors. While the primary concern in terms of potential adverse impacts on marine life is likely to be the overall contribution of many vessels to increasing background noise, efforts directed at quieting will likely be pragmatically and strategically applied on a ship-by-ship basis. Thus, in considering the range of possible measures to effectively address this issue, it is necessary and appropriate that emphasis be given to the diversity of ship types and their activities. Different approaches will almost certainly be necessary for different types of vessels. Flexibility and optimization are consequently important in developing practical and effective strategies for minimizing the introduction of incidental noise into the marine environment by commercial shipping.

*Strategic Plan: Mission Statement and categories of trends, developments, and challenges*

12 The Organization's Strategic Plan is set forth in Assembly resolution A.989(25) (20 November 2007). The Mission Statement provides that the mission of the Organization is, *inter alia*, the promotion of environmentally sound, efficient, and sustainable shipping through cooperation. The resolution also sets forth categories of identified trends, developments, and challenges; the issue of the introduction of incidental noise from commercial shipping operations falls within two of these categories. The category of globalization identifies the challenges for IMO as being proactive in identifying trends and developments affecting shipping, providing an effective and efficient response to shipping issues so as to avoid regional and unilateral actions, and involving all of IMO in formulating and adopting policy. Paragraph 2.2. The category of heightened environmental consciousness includes the IMO's challenges of

identifying and addressing shipping activities and incidents that could have an adverse impact on the environment and developing effective responses to shipping incidents to mitigate impacts on the environment. Paragraphs 2.5.1, 2.5.3.

13 The acceptance by the Committee of the work agenda item of minimizing the introduction of incidental noise from commercial shipping operations into the marine environment to reduce potential adverse impacts on marine life fulfils the Organization's Mission Statement and two of the categories of trends, developments, and challenges. Since the Organization provides the forum for addressing international issues affecting commercial shipping, its consideration of this issue will allow for all Member Governments to cooperate on this issue and thus promote environmentally safe, efficient, and sustainable shipping. Furthermore, by developing an effective and efficient response to this environmental challenge, the Committee will be proactive in addressing an identified issue which affects shipping. It will ensure that this issue is considered in a coordinated, consistent manner by all of IMO, thus benefiting the shipping industry, and should also help to avoid regional and unilateral actions. Finally, a comprehensive consideration of this issue by IMO will ensure that all activities and issues involved are fully considered and effective mitigation strategies, as appropriate, are developed.

*Strategic Plan: Strategic Directions*

14 The issue also falls within at least three of the identified Strategic Directions (SD) set forth in the Organization's Strategic Plan. First, SD1 recognizes that IMO is the primary international forum for technical matters of all kinds affecting shipping and that an inclusive, comprehensive approach will be the "hallmark" of IMO. Second, SD7 states that IMO will focus on reducing and eliminating adverse impacts by shipping on the environment by identifying and addressing possible adverse impacts and developing effective measures for mitigating and responding to such impacts. Third, SD13 recognizes that IMO will seek to enhance environmental consciousness within the shipping industry. The minimization of incidental noise from commercial shipping into the marine environment to reduce potential adverse impacts on marine life involves technical issues and IMO is the primary and appropriate international forum to develop a global response to this issue. Those attending IMO have the technical expertise to identify issues involved and develop effective mitigation strategies. Finally, since many in the shipping industry are unaware of this issue, working on this issue through IMO will enhance their consciousness of this environmental issue and help to ensure that the appropriate players become involved.

**Do adequate industry standards exist or are they being developed?**

15 Two instruments have been adopted by the Organization that address sources of noise on board ships that may adversely affect those on board: A.468(XII) and MSC/Circ.1014. While the sources of incidental noise may be the same whether they are affecting those on board or marine life (*e.g.,* machinery, propeller), these instruments only focus on the adverse impacts to those on board. Thus, even though there may be some limited benefits to marine life from the adoption of these instruments, they do not address the underwater potential adverse impacts to marine life.

**Do the benefits *vis-à-vis* maritime safety, maritime security or protection of the marine environment expected to be derived from the inclusion of the new item proposed justify such action?**

16 The benefits *vis-à-vis* maritime safety and protection of the marine environment justify the inclusion of this item on the work programme of the Committee. With regard to maritime safety, there are benefits that may accrue to the crew from the general reduction of noise from commercial shipping through the application of quieting technologies. Measures taken may further minimize the potential for hearing loss and enhance mariners' working conditions, including the ability to communicate verbally, hear audible alarms, and make clear-headed decisions that are necessary to ensure safety of navigation and other essential operations of the ship. They may also help address stress and fatigue caused by noise on board ships.

17 As noted in paragraphs 8-10 above, the introduction of incidental noise from commercial shipping may pose a host of potential problems for many marine animals and adversely impact their critical life functions. Since the number and size of commercial ships are growing, there will be an attendant and ever increasing amount of ambient noise entering the ocean from such ships. Additionally, much of the incidental noise associated with commercial vessels is – and may increasingly be – concentrated in relatively near-shore environments where marine life is also concentrated (Heitmeyer 2004, National Research Council of the U.S. National Academies 2003). Furthermore, the potential for increased vessel traffic in high latitude areas concomitant with retreating polar ice coverage is expected to result in the introduction of shipping noise in large areas that have not historically experienced it. Therefore, there is a pressing and timely need for proactive action to minimize incidental noise from commercial shipping operations to reduce potential adverse impacts on marine life.

**Has the analysis of the issue sufficiently addressed the cost to the maritime industry as well as the relevant legislative and administrative burden?**

18 The United States is not proposing that legally binding measures be adopted by the Organization and thus there are no mandatory costs to the maritime industry or legislative or administrative burdens. Notwithstanding, it must be recognized that if, for instance, guidelines are developed that recommend the installation of noise reducing technologies on board ships, then such technologies are likely to result in additional cost. There are, however, countervailing considerations. First, including such technologies at the design and construction phase is much more efficient, cost-effective, and practical than retrofitting them at a later stage or affecting where a ship operates or its operational practices. Second, as noted above, sound produced as an incidental by-product of vessel operation serves no particular function in the transportation of goods and may, to some extent, represent wasted energy. Although the underlying technical issues involved are highly complex and need further consideration and validation, quieter vessels could be more cost-effective and efficient to operate and maintain. Thus a minimization of noise may represent a reduction in both propeller cavitation and ship-board vibration and, consequently, result in reduced operational and maintenance costs.

**Specific indication of the action required**

19 The Committee is invited to 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 and, in particular, to develop non-mandatory technical guidelines for ship-quieting technologies as well as potential navigation and operational practices.

An emphasis should be on practical, effective solutions that can be implemented by the shipping industry.

**Should the item be assigned a high priority?**

21 Paragraph 2.14 of the annex to MSC-MEPC.1/Circ.1 provides for the consideration of establishing the priorities of items on the Committees' work programmes. It is generally noted that a higher priority should be assigned to items that can be shown, or estimated, to have the greatest effect on such things as protection of the environment and the highest ratio of benefit to be gained from the implementation of the proposal compared with the cost of its implementation. The United States believes that this issue warrants high priority. As set forth above, the introduction of incidental noise from commercial shipping operations into the marine environment is growing because of the increasing number and size of ships and such noise may pose adverse impacts on critical life functions of many marine animals. Moreover, even though this issue involves commercial shipping and the Organization is the international entity charged with the responsibility for adopting measures related to shipping, there has been no previous consideration of this issue by the Organization and mariners in large part are unaware of it. Action taken to address it can therefore be expected to have significant benefits. Moreover, since the United States is proposing non-mandatory measures, the cost of any such action is likely to be small compared to the potential benefits.

22 The issue also satisfies several of the specific factors that are to be considered in assigning an issue high priority. The adoption by IMO of measures to minimize the introduction of incidental noise from commercial shipping into the marine environment would promote the widest possible implementation of such measures by the shipping community as a whole and thus avoid regional or unilateral action to address it. Second, there are some that consider noise as a form of pollution (Firestone and Jarvis 2007, Haren 2007, Scott 2007, McCarthy 2004) and it satisfies the factor of the adoption of measures which aim substantially at preventing pollution. Incidental noise from commercial shipping does not, unlike persistent forms of pollution such as heavy metals or greenhouse gases, remain in the marine environment after it is introduced. Thus, the application of strategies to quiet vessel, including in particular quieting technologies, has the potential to reap immediate environmental benefits for marine life. Third, as noted above, quieting commercial ships has a significant likelihood that it will improve the health and safety of ships' crews and any passengers on board the ship.

**What is the target completion date?**

23 The United States believes that three or four sessions of the Committee are necessary to complete its work on this issue. Therefore the target completion date is either MEPC 61 or MEPC 62; however, progress reports should be submitted to each intervening session of the Committee.

***

## ANNEX 2

References and other literature considered in the development of this document:

Andrew, R. K., B. M. Howe, and J. A. Mercer. 2002. Ocean ambient sound: comparing the 1960s with the 1990s for a receiver off the California coast. Acoustics Research Letters Online 3, 65-70.

Andrew, R. K., B. M. Howe, and J. A. Mercer. In press. Long-Time Trends in Low-Frequency Ambient Noise for Four Sites off the North American West Coast. Journal of the Acoustical Society of America.

Bachman, R., T. Schey, W. Philip, N. O. Booth and F. J. Ryal. 1996. Geoacoustic databases for matched-field processing: preliminary results in shallow water off San Diego, California. Journal of the Acoustical Society of America 4, 2077-2085.

Bartlett, M. L. and G. R. Wilson. 2002. Characteristics of small boat signatures. Journal of the Acoustical Society of America 112, 221.

Cato, D. H. 1976. Ambient sea noise in waters near Australia. Journal of the Acoustical Society of America 60, 320-328.

Cato, D. H. and R. D. McCauley. 2002. Australian research in ambient noise. Acoustic Australia 30, 13-20.

Cummings, J. 2007. Regulating ocean noise: entering uncharted waters. Journal of International Wildlife Law and Policy 10, 101-107.

Curtis, K. R., B. M. Howe and J. A. Mercer. 1999. Low-frequency ambient sound in the North Pacific: long time series observations. Journal of the Acoustical Society of America 106, 3189-3200.

Erbe, C. 2002. Hearing abilities of baleen whales. Defense R&D Canada – Atlantic. Contractor report #DRDC Atlantic CR 2002-065.

Erbe, C. and D. M. Farmer. 2000. A software model to estimate zones of impact on marine mammals around anthropogenic noise. Journal of the Acoustical Society of America 108, 1327-1331.

Erbe, C. and D. M. Farmer. 1998. Masked hearing thresholds of a beluga whale (*Delphinapterus leucas*) in icebreaker noise. Deep Sea Research Part II: Topical Studies in Oceanography 45, 1373-1388.

Fay R. R. 1988. Hearing in vertebrates: A psychophysical databook (Winnetka, IL: Hill-Fay Associates).

Firestone, J. and C. Jarvis. 2007. Response and responsibility: regulating noise pollution in the marine environment. Journal of International Wildlife Law and Policy 10:109-152.

Fletcher, H. F. 1940. Auditory patterns. Review of Modern Physics 12, 47-65.

Gray, L. M. and D. S. Greeley. 1980. Source level model for propeller blade rate radiation for the world's merchant fleet. Journal of the Acoustical Society of America 67, 516-522.

Greene, J., C. R. and S. E. Moore. 1995. Man-made Noise. Pp. 101-158 *in* J. W. Richardson, J. Greene, C.R., C. I. Malme and D. H. Thomson (eds.), Marine Mammals and Noise (Academic Press, New York).

Haren, A.M. 2007. Reducing noise pollution from commercial shipping in the Channel Islands National Marine Sanctuary: a case study in marine protected area management of underwater noise. Journal of International Wildlife Law and Policy 10:153-173.

Hatch, L. T., C. W. Clark, R. Merrick, S. Van Parijs, D. Ponirakis, K. Schwehr, M. Thompson, and D. Wiley. (In press). Characterizing the relative contributions of large vessels to total ocean noise fields: a case study using the Gerry E. Studds Stellwagen Bank National Marine Sanctuary. Environmental Management.

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

Kipple, B. M. and C. M. Gabriele. 2003. Glacier Bay Watercraft Noise: Report to Glacier Bay National Park by the Naval Surface Warfare Cent-Detachment Bremerton. Technical Report NSWCCD-71-TR-2003/522.

McCarthy, E. 2004. International Regulation of Underwater Sound: Establishing Rules and Standards to Address Ocean Noise Pollution. Kluwer Academic Publishers, Boston, Massachusetts.

McDonald, M. A., J. A. Hildebrand, and S. M. Wiggins. 2006. Increases in deep ocean ambient noise in the northeast Pacific west of San Nicholas Island, California. Journal of the Acoustic Society of America 120, 711-718.

Morisaka, T., M. Shinohara, F. Nakahara, and T. Akamatsu. 2005. Effects of ambient noise on the whistles of Indo-Pacific bottlenose dolphin populations. Journal of Mammalogy 86, 541-546.

National Research Council of the US National Academies (NRC). 2003. Ocean Noise and Marine Mammals. National Academy Press, Washington, District of Columbia.

Nowacek, D. P., L. H. Thorne, D. W. Johnston, and P. L. Tyack. 2007. Responses of cetaceans to anthropogenic noise. Mammal Review 37, 81-115.

Parks, S. E., C. W. Clark, and P. L. Tyack. 2007. Short- and long-term changes in right whale calling behavior: The otential effects of noise on acoustic communication. Journal of the Acoustical Society of America 122, 3725-3731.

Payne, R. and D. Webb. 1971. Orientation by means of long range acoustic signaling in baleen whales. Annals of the New York Academy of Sciences 188, 110-141.

Piggott, C. L. 1964. Ambient sea noise at low frequencies in shallow water of the Scotian Shelf. Journal of the Acoustical Society of America 36, 2152-2163.

Richardson, W. J., Greene, C. R., Malme, C. I., & Thomson, D. H. (Eds.). (1995). Marine mammals and noise (Academic Press, New York).

Ross, D. G. 1976. Mechanics of Underwater Noise (Pergamon Press, New York).

Ross, D. G. 1993. On ocean underwater ambient noise. Acoustics Bulletin Jan/Feb 5-8.

Scott, K.N. 2007. Sound and cetaceans: a regional response to regulating acoustic marine pollution. Journal of International Wildlife Law and Policy 10:175-199.

Southall, B.L. 2005. Shipping Noise and Marine Mammals: a Forum for Science, Management, and Technology. Final Report of the National Oceanic and Atmospheric Administration (NOAA) International Symposium. U.S. NOAA Fisheries, Arlington, Virginia, May 18-19, 2004, 40 pp. http://www/nmfs.noaa.gov/pr/acoustics/shipnoise.htm.

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.

Soto, N. A., M. Johnson, P. T. Madsen, P. L. Tyack, A. Bocconcelli, and J. F. Borsani. 2006. Does intense ship noise disrupt foraging in deep-diving Cuvier's beaked whales (*Ziphius cavirostris*). Marine Mammal Science 22, 690-699.

Ward, W. D. 1997. Effects of high-intensity sound. Pp. 1497-1507 *in* M. J. Crocker (Ed.), Encyclopedia of acoustics vol. III (John Wiley & Sons, Inc., New York).

Wenz, G. M. 1962. Acoustic ambient noise in the ocean: spectra and sources. Journal of the Acoustical Society of America 34, 1936-1956.

Wenz, G. M. 1969. Low-frequency deep-water ambient noise along the Pacific Coast of the United States. U.S. Navy Journal Underwater Acoustics 19, 423-444.

Worley, R. D. and R. A. Walker. 1982. Low-frequency ambient ocean noise and sound transmission over a thinly sedimented rock bottom. Journal Acoustical Society of America 71, 863-870.

Zakarauskas, P. 1986. Ambient noise in shallow water: a literature review. Canadian Acoustics 14, 3-17.

Zakarauskas, P., D. M. F. Chapman and P. R. Staal. 1990. Underwater acoustic ambient noise levels on the eastern Canadian continental shelf. Journal Acoustical Society of America 87, 2064-2071.

INTERNATIONAL MARITIME ORGANIZATION

IMO

E

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.

  - *Southall 2005:* Most (83%) of the acoustic field surrounding large vessels is the result of propeller cavitation.
  - *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.
  - *Southall and Scholik-Schlomer 2008:* SEAFAC studies indicate propeller-radiated noise is highly dependent on vessel speed.
  - *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.
  - *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).
  - *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.

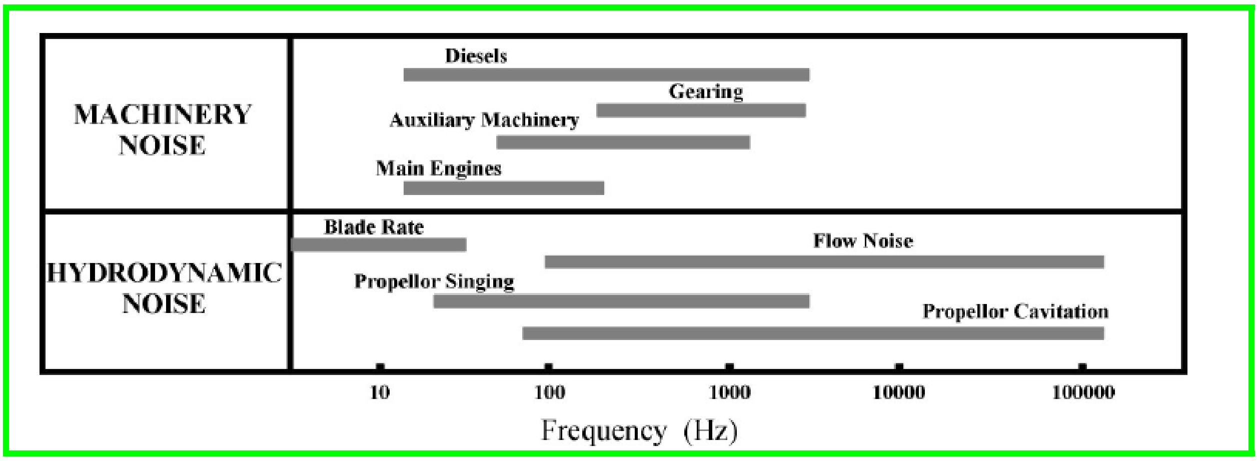
noise radiated through the hull is a source of underwater noise, it is less clear how significant it is as source of the total external noise generated; the range of the noise source and the inverse square law need to be taken into account.

- *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.

  - *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 $\pm$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 ($21^{st}$ -$24^{th}$ 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.

___

INTERNATIONAL MARITIME ORGANIZATION

IMO

E

MARINE ENVIRONMENT PROTECTION COMMITTEE
60th session
Agenda item 18

MEPC 60/18
18 December 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". The Correspondence Group was established 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. This is the second 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 10 |
| ***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 59/19; MEPC 59/19/1; MEPC 58/19; MEPC 57/INF.4 and MEPC 57/INF.22 |


**Introduction**

1 MEPC 58 approved the inclusion of a new high priority item in the work programme of the Committee on "Noise from commercial shipping and its adverse impact on marine life". The Correspondence Group continued its work on this issue between MEPC 59 and MEPC 60. Two rounds of comments were exchanged. While the work is ongoing, this document summarizes the interactions and progress on this issue thus far.

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 | Republic of Korea |
| Australia | Japan | Singapore |
| Bahamas | Liberia | Sweden |
| Canada | Marshall Islands | United Kingdom |
| China | Netherlands | United States |
| Germany | Panama | |
| CLIA | IFAW | IWC |
| UNEP/CMS | IMAREST | WWF |
| FOEI | INTERTANKO | |
| ICOMIA | ISO | |
| ICS | IUCN | |

**Substantive issues**

3 The Correspondence Group discussed a number of technological issues which are set out in annexes 1 and 2. There are questions and proposals posed in both annexes and input on these issues is welcome in order to progress this work.

4 Several participants suggested that simplicity may be the best approach and that the Correspondence Group should concentrate its efforts on the major element of cavitation. It was suggested that the other aspects of incidental underwater noise generated from shipping should be noted but at this stage simply retained for future reference.

5 A few participants raised the issue of the regulatory framework. In doing so, it was noted that there are other entities that are working on regional legislation for various types of noise. With regard to this issue, it must be emphasized that the Correspondence Group's terms of reference are confined to the work on *non-mandatory* technical guidelines for ship-quieting technologies as well as potential navigation and operational practices. Therefore, the Correspondence Group was not instructed to develop a regulatory framework for this issue.

6 The Correspondence Group noted that two groups have been working on the development of standards for underwater noise. Information on these efforts is appended as annex 3.

7 In an effort to support and guide research efforts on this issue, Correspondence Group Members were asked to identify the research needed in this area as well as identify the facilities where research on the issue of underwater noise from commercial shipping is being done or could be done. It was suggested that such research should be done simultaneously with the work of the Correspondence Group. The responses are provided in annex 4.

**Outreach efforts**

8 In an attempt to obtain additional input from those entities that may have useful information on this issue, the Correspondence Group approached additional stakeholders. The Group first approached national shipowners. Feedback included the important points that while some larger shipping companies have an impact on how a ship is designed and built, most buy ships that have already been built or on which construction has already begun. Therefore, shipowners would in many instances not have an impact on noise reduction measures since the vessel design stage has already been completed. It was suggested that perhaps shipyards may have more input on ship design.

9 The Group also approached model basins for their input. Model basins generally carry out hydrodynamic tests in tanks to test ship models for the purpose of designing a new, full-sized ship or refining the design of a ship to improve the ship's performance at sea. Annex 5 is a listing of the model basins that were approached, the letter that was sent, and a summary of the responses received.

**Action requested of the Committee**

10 The Committee is invited to take note of the report of the Correspondence Group, provide input to the questions and proposals set out in the annexes, and take any other action it deems appropriate.

***

## ANNEX 1

## TECHNOLOGICAL ISSUES[1]

One participant stated that before we try to identify possible countermeasures, we need to assess the potential contribution for each of the ship components to the radiated sound power. Otherwise the discussion would become too complex and unspecific.

What are your thoughts on this? Is this possible to do? Should it be done before we try to identify possible ways forward on individual ship components?

The information set forth below in this annex pose the same series of questions for the following three areas: (1) the propeller, (2) the machinery, and (3) the hull. For each of these areas, the following overarching questions have been posed: A) identified issues, B) type of noise produced, C) how do we fix the identified issues, and D) other information pertaining to the designs listed in C(1).

**I Propeller**

A. Identified Issues

1. Cavitation. The initial and primary focus of the Correspondence Group's efforts is expected to be on issues related to propeller cavitation since it is known to be a significant (and often dominant) source of low frequency underwater noise from large vessels:

   a. Initial design of the propeller
   b. Damage causing a change of its hydrodynamic shape
   c. Marine growth
   d. When speed of a ship is not adjusted by the rate of propeller rotation, but 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
   e. Shallow propulsion immersion--ships in ballast produce more cavitation noise than when fully loaded

2. Blade rate tonal sounds: non-uniform distribution of low frequency, as whether noise reduction needs to focus on specific bandwidths/spectral components, and how to ensure that in doing so acoustic energy is not re-distributed to other low or high frequency output.

B. Type of noise produced

1. Cavitation is broadband but generally and predominantly low frequency; frequencies <100 Hz at high propeller loads, continuous spectrum; this spectrum has a broad "hump" at low frequencies (about 50 Hz) followed by a continuum that decreases by 6 db per octave; at high speeds the continuum can contribute a significant fraction of radiated noise power.

2. Blade rate tonal sounds are narrow-band and also generally low frequency.

[1] As noted previously, the Correspondence Group is focusing first on technologies and then will take up the issues pertaining to the animal/receptor part of the equation.

3. Depending on the pitch settings and loading of a propeller, a controllable reversible propeller (CRP) propeller may generate higher frequency noise.

4. Propeller depth is important in terms of long-range noise propagation.

C. <u>How do we fix the identified issues—are there any things that have been done to other types of ships that can be used on commercial ships?</u>
*(One participant stated that propeller design is critical to efficiency as well as minimizing the sound generated)*

1. Design:
   a. main dimensions of the hull and the hull/propeller interaction are optimized to improve the wake field around the propeller and reduce hull resistance;
   b. twin screw propulsion have smaller propeller loadings and a more homogenous wake field therefore better working condition for the propellers compared to single-screw propellers;
   c. wing thrusters;
   d. surface piercing, non-cavitating, and advanced blade section propellers; (one participant stated that non-cavitating propellers probably do not exist. It is more realistic to speak of minimizing cavitation.);
   e. electric and Voith-Schneider propellers;
   f. contra-rotating propellers (one participant stated that these provide overall improvement in performance but do not necessarily reduce noise), propellers with tip (winglet), and ducted propellers;
   g. designs with tips without added weight, large diameters; low RPMs, long blade lengths; bulbs on the tips, and/or refined trailing edges;
   h. propeller pods to place the blades deeper in the water column; single screw systems with open (high) screw propulsion to allow for a smoother (less turbulent) wake field; (One participant stated that draft increases may be an issue. Pods are good for maneuverability and they are quieter on board, but their development has not necessarily been driven by reducing radiated noise.);
   i. forward-skewed nozzle-propeller blades to allow for increased cavitation inception speeds and reduced cavitation on the leading edge of the blade; (One participant agreed with this statement in general.);
   j. podded propulsion systems (e.g., azipods or 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;
   k. water-jet propulsion;
   l. pod propulsion systems which allows long propeller shafts to be avoided and can provide minimum disturbed flow to the propeller;
   m. Praire-System which involves blowing air into the flow around the propeller through tiny holes in the blades. *See also* the attached tables from *Southall and Scholik-Schlomer 2008;* and (One participant stated that these are likely to be too complicated for commercial ships. They have been developed and applied to warships which have particular design constraints.);

n. propellers constructed of composite material – reduce vibrations, pitch adaptive (i.e., as the propeller turns it shapes itself to the optimum angle of attack with regard to the velocity of wake field inflow).

2. Damage to the propeller is usually repaired during drydocking.

3. Marine growth does not usually occur given the high usage of ships, but barnacles can cause premature and more severe cavitation if it goes unnoticed.

D. <u>Other information pertaining to the designs listed in paragraph C(1)</u>

1. How much sound reduction can be obtained by using the above designs?

One participant made the following observations: Optimization hull/propeller design is the primary means of improving the wake field around the propeller and improving the propulsive efficiency (C1(i)). The propelling options and propeller designs listed in C1(ii) through C1(xii) are all viable options of increasing the propulsive efficiency and reducing cavitation of the propeller. It is difficult to predict the amount of reduction in cavitation achievable by using a particular option or a combination of options without further studies. Propellers and propulsion systems vary according to the type of vessels, however, optimization of hull/propeller interaction may be done on all types of ships, which will reduce propeller cavitation and the radiated noise, except it may be for deeper submerged propulsion systems, such as the podded propellers, and water jet propulsion.

2. Are the designs listed in C(1) being used on commercial ships?

a. If so, on what types of ships?
One participant noted that different types of commercial vessels have different types of propulsion systems: the fixed pitch, cavitating, single screw, low RPM propellers are mainly used for bulk and OBO carriers and tankers. Water jet propulsion (which is especially popular for high speed ferries and it is growing in popularity) is used mainly in specialized smaller size vessels, and podded propellers are mainly used in ferry/passenger/large slower ships – there are specific benefits and limitations for each type of propulsion systems.

b. If not, why not?
No responses were received to this question.

c. Is their frequency of use likely to increase in the near future as a result of other realized commercial ship design pressures (e.g., fuel efficiency, carbon emissions)?
One participant stated that it is anticipated that with the new vessel design index and air emission requirements being finalized by IMO, vessel owners, designers and builders will place greater emphasis on hull/propeller interactions. It is anticipated that advanced propeller designs and propulsion systems will also be used.

3. Is there anything in each of the designs that we should consider relating to their field of application, their operational envelop, their technical status, and potential future or present relevance?

One participant stated the following:

One of the main noise sources is definitely the cavitating propeller. Therefore we need more insight into the complex physical behavior of cavitation and its related consequences like noise and pressure fluctuations, also those reflected by the ship's hull.

For years the fixed pitch propeller will be the main propulsion unit for commercial ships, the second in line will be the controllable pitch propeller. Therefore our efforts must be put on these units.

The important task is to find which type of cavitation (sheet, bubbles, clouds, vortices) contributes to the measured noise level. Knowing this we can start talking about possible countermeasures.

If we look into the available information (mostly from navy ship investigations), one can assume that for good propeller designs an improvement of about 10 dB on the noise output can be expected. This can also be achieved when improving the setting conditions for controllable pitch propellers. But keep in mind that this normally goes hand in hand with a reduction of efficiency. This needs special attention when talking to owners. On the other hand we should remember that many of the available noise data for different ships are years old and therefore are related to much worse propeller design compared to what we have today. In other words, the improvements we can expect may be much higher.

Another participant suggested that we limit our focus in this area to minimize propeller cavitation to fixed pitch propellers and controllable pitch propellers and to twin vs. single screw arrangements.

Another participant stated the following:

It is to be expected that most of the ships in the foreseeable future (> 90%) will be propelled by conventional screw-propellers of more or less sophisticated design driven by an engine inside the ship connected to the propeller via a shaft. The reason for this arrangement is its high efficiency and mechanical simplicity. I recommend not to look into too much detail in other systems like pods, Voith-Schneider-Propellers and other systems which will always have a limited range of application and none for high powered ships.

The potential in the screw-propeller when designing it for low underwater radiated noise is not known because it has not been a criterion in the past. However, from experience with noise levels from merchant ships and from naval ship propellers, it may be in the order of 10 dB for a good design and much more than that for an originally bad design. This may be true for a fixed pitch propeller.

For a controllable pitch propeller things are more complex. Ships with this propulsion system can be categorized in ships with constant shaft speed adjusting speed only with pitch setting and ships which adjust speed by a combination of shaft speed and pitch setting. This combination is usually fixed for maximum fuel efficiency. Changing the combination for minimum noise output results in possibly 10 dB less noise but unacceptable working conditions for the engine.

Note that the question for the propeller is not only cavitation but more importantly which type of cavitation as they may have very different noise characteristics.

Any application of principles to reduce radiated noise will require research, which can easily be identified and described. It is to be expected that the effect on fuel efficiency will not be positive.

Another participant, in responding to the above point that reduced cavitation and noise would likely produce an adverse effect on fuel efficiency, stated that this view is markedly different from what they have heard.

Yet another participant stated the following:

Towing tank tests to determine skin friction and hull/propeller interactions with different types of propellers and hull forms, and validating the results with full scale designs should be done. Making the results available to the design community will help future design efforts.

Since the vessel design parameters and the operating conditions are rarely the same, the optimization of hull/propeller interaction and selection of the propulsion system should also be performed based on the vessel operating conditions.

**II Machinery**

A. Identified issues

1. Operating machinery because of vibrations that radiate via the hull; becomes significant for ships operating at low speeds (i.e., with low prop loadings as in harbor approach).

2. Reduction gears of medium speed engines.

3. Medium speed diesel generators.

B. Type of noise produced

1. Operating machinery is at frequencies <100 Hz at lower ship speeds.

2. Reduction gears of medium speed engines may generate noise at higher frequencies >1kHz.

3. Medium speed diesel generators sometimes contribute considerably to radiated noise >50Hz when not masked by cavitation noise.

4. Machinery-induced noise may remain constant at lower ship speeds (e.g., diesel generator noise is not dependent on ship operating speeds).

C. How do we fix the identified issues—are there things that have been done to other types of ships that can be used on commercial ships?

1. Equipment and propulsion systems may be fine-tuned to achieve more appropriate harmonics.

One participant stated that a) varying degrees of benefit may be obtained with the application of technologies as listed. Slow and medium speed diesel engines are balanced for even load generation between the cylinders and the resultant harmonics; b) they are generally used; and c) their use is expected to increase.

2. Resilient mountings for medium speed engines and auxiliary machinery; double stage mounting system may reduce noise transfer from diesel generators to ship structures to a substantial degree; resilient mounting for piping (i.e., ducts of exhaust gas system in all ship types); active mounting systems.

One participant stated that:
a) Resilient mountings are rarely used in the commercial large ocean going vessels; however, large diameter exhaust/stem pipes are generally resiliently mounted; and
b) cost/benefit.

Another participant noted that 2-stage mounts (rubber mounting, then hard platform, then another rubber mounting) are even better – 20 dB or more reduction could be achieved if well designed. Single stage at a minimum recommended. Resilient mountings shouldn't cost significantly more, mounting of some kind is needed so it might as well be rubber.

3. Variable speed pumps, optimum electric load control (reducing the number of auxiliary engines operating for power generation at a given time).

One participant stated that:
a) Not widely used;
b) cost/benefit; and
c) use expected to increase.

4. Acoustic filters, desurgers, and flow control valves may minimize sound from fluids to and from equipment.

One participant stated that:
a) Not generally used; and
b) cost/benefit.

5. Propulsion: electric drive propulsion; hybrid power generation using fuel cells and/or a combination of solar, wind, and shore power; pod propulsion so that there are smaller power plants which can be mounted in a more shock absorbing manner and be placed in a part of the ship less likely to conduct sound; diesel-electric.

One participant stated that:
a) electric drive propulsion systems are mainly used in commercial vessels where reduced vibration is needed, such as passenger vessels and hybrid power generation is not used except for a few demonstration projects; and
b) electric drive propulsion has a lower propulsion efficiency and hybrid power is still considered experimental.

6. Airborne noise insulation—cladding of a quiet ship's interior.

One participant agreed that this could be of use.

Another participant stated that other than the cruise vessels, machinery rooms of a commercial vessel are not cladded to reduce air borne noise.

7. Damping treatment to structures; adding buffering layers under or within the hull.

One participant stated that these are not used in commercial vessels. Another participant stated that these would be secondary to mounting.

8. Active mounting systems.

One participant stated that these are not used in commercial vessels.

Another participant stated that this is still at concept and military prototype stage. It is still a long way to go before commercial application.

9. Engine synchronization.

One participant stated that only the auxiliary engines/shaft alternators are synchronized for parallel power generation. Multiple main engines for master/slave operation are sometimes synchronized.

10. Identify/consider benefits in terms of reduced maintenance of propulsion systems from quieting technology treatments.

One participant stated that well-balanced and optimal used of machinery is expected to generate less vibration that will reduce wear, tear and fatigue of the machinery/systems and reduce maintenance - Performance based maintenance is designed to do just that. Also, reduced propeller cavitation will require less propeller maintenance.

11. Selection of low-noise equipment in the first place.

12. Isolate large slow speed diesels and gear-boxes.

D. Other information pertaining to the designs listed in paragraph C(1)

1. How much sound reduction can be obtained by using the above?

One participant stated that overall there maybe 15-20 dB reduction in noise from machinery fixes.

Another participant stated that the amount of radiated noise reduction that can be achieved needs to be researched. (a) Resilient mountings for main engines of large commercial vessels may not be feasible due to the weight of the engines. These mountings for auxiliary diesel engines and machinery are feasible and will reduce hull transmitted noise, but the cost of such application may have to be justified. (b) Variable speed pumps and optimum electric load control are expected to reduce vibration, optimize operation of auxiliary engines and can be applied on all types of vessels, given the cost/benefit analysis. (c) Unless the propulsion efficiency of electric drives is improved, these systems may only be used on board cruise/passenger vessels. Hybrid power generation may come of age for application on board the nearshore vessels.

2. Are they being used on commercial ships?
   a. If so, on what types of ships?
      No responses were received to this question.
   b. If not, why not?
      No responses were received to this question.
   c. Is their frequency of use likely to increase in the near future as a result of other realized commercial ship design pressures (e.g., fuel efficiency, carbon emissions)?
      No responses were received to this question.

3. Is there anything that we should consider relating to their field of application, their operational envelop, their technical status, and potential future or present relevance?

One participant noted:
Medium speed engines as one of the dominating noise generators are resiliently mounted in modern ships reflecting the need for crew comfort. Observing the efficiency of these mountings there is a large range of improvement in the order of 10-15 dB reduction with little effort. A comparison is possible of cargo ship diesel generator installations and those on mega-yachts and cruise liners. There is no other pressure to improve noise form machinery except crew comfort.

Another participant noted that there is no real impediment to resilient mountings, there will be cost only.

III. **<u>Hull:</u>**
A. <u>Identified issues</u>

1. Flow noise around the hull is generally minimal but increases significantly at low frequencies as the vessel speed increases.

   a. Flow around underwater appendages (what these are needs more discussion; however,

One participant stated that they are stabilizers, extra keel structures, sea chests, orifices in the hull. Each of these will generate noise at a range of frequencies related to vessel speed.

Another participant stated that they vary by vessel type, some of the important ones are: i) Skeg shape/trailing edge; ii) Bow thruster scallops/grids, minimizing resistance of hull openings; iii) Rudder profile and propeller; iv) "A" frame).

2. Hull configuration and wake field.

B. Type of noise produced

1. Appendage noise are of low intensity at frequencies below <20 Hz.

C. How do we fix the identified issue

1. Hull design.

One participant stated that new hull designs of commercial ships are usually optimized and towing tank tested which may include break bulk carriers, tankers, OBOs, container vessels, Ro-Ros, etc; cost is usually the primary reason and there may not be enough incentive for the designer/builder to optimize the design; usage is likely to increase in the near future due to IMO regulations on the vessel design index to reduce GHG emissions.

2. Underwater appendages could be streamlined and rudder (rudder bulb) and skeg designs optimized to improve flow of water and to reduce drag and noise.

One participant stated that the hull, appendages and the bulbous bow are designed according to vessel type and other factors; cost is usually the primary reason and there may not be enough incentive for the designer/builder to optimize the design; usage likely to increase.

3. Reduce turbulence-elliptical bow shape; no abrupt change of shape in the waterline; minimization and alignment of appendages and fittings; flush welds, undistorted plates, and smooth paint works; optimize hull dimensions.

One participant stated that there are many factors that are considered for the design of the bow and bulbous bow. Undistorted plates are more a concern of vessel construction and faired and smooth hull plates will certainly reduce the skin friction. Smooth hull coating will mainly depend on the condition of the hull plates; usage is likely to increase.

Another participant stated that the information they had suggested that such coatings on both the hull and propellers are becoming more common as a way of optimizing performance by maintaining a good finish.

4. Hull cleaning/silicon based coating to reduce hull resistance and propeller loading

One participant stated that for all ships, hull cleaning of non-silicon based coating is performed periodically. Hulls with silicon based coating are still not very common; In-water hull cleaning of hulls with non-silicon based coating is performed periodically, depending on the time, cost, regulations and the amount of fouling. During scheduled drydocking, the same functions are routinely carried out. The jury is still out on the silicon based coating; usage is likely to increase.

D. Other information pertaining to the designs listed in paragraph C(1)

1. How much sound reduction can be obtained by hull design?

No responses were received to this question.

2. Is this being done on commercial ships?

   a. If so, on what types of ships?
   No responses were received to this question.

   b. If not, why not?
   No responses were received to this question.

   c. Is their frequency of use likely to increase in the near future as a result of other realized commercial ship design pressures (e.g., fuel efficiency, carbon emissions).

   No responses were received to this question.

3. Is there anything that we should consider relating to their field of application, their operational envelop, their technical status, and potential future or present relevance?

   One participant stated that there is a good relationship between hull drag and hydrodynamic noise. Probably at this stage there is no much to be gained (compared to propeller and machinery approaches) as hulls are already fairly well optimized. Intersects with commercial imperative are necessary for efficiency.

   Another participant noted that the only effect of hull design influencing noise is the effect on resistance (limited) and on the wake field to the propeller (potentially high). This is always in the focus of designers because it is very much linked to fuel efficiency.

   Another participant noted that the range of noise impact of all the above can only be fully understood and thus sensibly mitigated when taking into account the context of the environmental conditions in which the vessel is operating such as:

   - existing ambient noise levels at the frequency of interest; and
   - sound propagation conditions such as:
     1. layer depth;
     2. CZ potential;
     3. sea state; and
     4. water depth, bathymetry, and sea bed type (One participant noted that this could lead to the development of a world map of noise propagation something that many navies already have).

**COMMENTS ON TABLES BELOW**

One participant stated that all the measures in tables for the three contributing components—the propeller, the machinery, and the hull—are smartly consolidated. They suggested that the Correspondence Group limit its focus to the following items:

- minimize propeller cavitation for fixed pitch propellers and controllable pitch propellers;
- twin vs. single screw arrangement;
- hull shape configuration, wake field;
- maintenance: propeller geometry and fouling, hull fouling; and
- speed reductions.

They also stated with regard to MEPC 59/19/1 (FOEI, IFAW) paper: Almost none of the measures to minimise cavitation have been implemented to decrease the radiated noise, but to avoid erosion or to improve propulsion efficiency.

Another participant basically agreed with the above views about the main topics to focus on with an emphasis on operations.

On the design side:

- minimize propeller cavitation;
- twin v. single screw arrangement; and
- hull shape configuration, wake field.

On the operation side

- speed reductions; and
- routeing.

**NEW DESIGN OPTIONS FOR VESSEL-QUIETING**

| One participant asked whether this table is based on single platform gains and what happened in areas of high shipping activity? Additionally, it was suggested that another column be added to note the reduction in impact in relation to the species, that is the environmental benefit. | **Advantages/Benefits** | **Disadvantages/ Challenges** | **ROUGH Cost Estimates (Low, Med, High)** | **Anticipated GENERAL Magnitude of Quieting (Low, Med, High)** |
|---|---|---|---|---|
| **Minimize Propeller Cavitation (propeller shape, configuration, size, etc.)** | Reduction of tip vortex; reduction of pressure pulses; forward-skewed ducted props expected to increase cavitation inception speeds, hence lower cavitation noise levels (duct can serve for site of injecting air and also a *de facto* prop guard); "ring" propeller can eliminate tip vortex | Variable results in terms of quieting, operational efficiency | **Variable (potentially low)** | **High** |
| **Minimize Propeller Cavitation (variable pitch propellers)** | Good in terms of radiated noise at nominal pitch; can identify minimum noise output | Poor in terms of operational efficiency; Potentially misused for speed control | **High** | **Variable (potentially high)** |
| **Twin vs. Single Screw Propulsion Systems** | Enables the use of large diameter propellers that turn more slowly; System redundancy is safety benefit | Only have half the thrust per system; major difference in design of entire ship | **High** | **Variable (potentially high)** |
| **Podded Propulsion (Azipods)** | Potentially great improvement of wake field; reduced cavitation; reduced vibration | Not sufficiently powerful yet; high electrical noise; efficiency can be poor | **High** | **Moderate (especially for low-frequencies, but some high frequency tonal spikes)** |

| | | | | |
|---|---|---|---|---|
| **Hull Shape/Configuration** | Improvement of wake field (may also improve efficiency) | Some difference in design of entire ship; Requires model testing | **Medium (highly uncertain)** | **High (especially for low frequency)** |
| **Air Injection Systems (ducted air emission)** | Air injection around the prop (bubble shield in front of and around the propeller) could be advantageous in terms of noise (requires slightly more power); inject air around propeller tips may work but has to be investigated | Navy-type approach is too expensive and difficult to maintain;<br>May be some increase in radiated noise | **Medium** | **Uncertain** |
| **Passive Equipment Mounts (Vibration Isolators)** | Reduces Structure-borne path noise | Increasingly less effective for frequencies below 200 Hz for large diesel engines due to large mass; requires dynamically stiff foundations (impossible for very large engines) | **Mounts cheap but overall application can be very high** | **Medium to High (depending on frequency)** |
| **Dynamic (Active) Equipment Mounts** | Show significant promise; work well in other applications | Not widely available yet (still somewhat experimental) | **High** | **Potentially High** |
| **Pump Isolations, Acoustic Filters, Pipe Hangers** | Pretty simple generally | Takes some engineering effort; may not be relevant for consideration because of masking from propulsion noise on most large ships (very small point – way down the list) | **Medium** | **Low to Moderate** |

| | | | | |
|---|---|---|---|---|
| **Acoustic Insulation** | Reduces AB & SB Transmission; for engine room only | More directed to minimizing airborne versus underwater noise; This likely further down the list than propulsion systems | **Low [$1-$4/sq. ft]** | **Low to Moderate** |
| **External and Internal Coatings (Dampening Products)** | Relatively simple | Effectiveness depends on material 'compliance' and thickness; some limitations for internal coatings; maintenance can be very difficult on external coatings; Both only work at higher frequencies (200 Hz +); secondary consideration | **Low [$8-$12/sq. ft]** | **Low to Moderate** |
| **Maintenance** | Reduce machinery source level; can increase overall efficiency of propulsion and other systems | Cost can be significant if much greater than nominal schedule | **Variable** | **Variable (potentially moderate to high)** |

***RETROFITTING OPTIONS FOR VESSEL-QUIETING***

| Treatment | Advantages/Benefits | Disadvantages/ Challenges | ROUGH Cost Estimates (Low, Med, High) | Anticipated GENERAL Magnitude of Quieting (Low, Med, High) |
|---|---|---|---|---|
| **Minimize Propeller Cavitation (propeller shape/configuration)** | Reduction of tip vortex and pressure pulses; forward-skewed props should increase cavitation inception speeds | Variable results in terms of quieting, operational efficiency | **Variable (potentially high)** | **High** |
| **Minimize Propeller Cavitation (variable pitch propellers)** | Good in terms of radiated noise | Poor in terms of operational efficiency | **High to very high** | **Variable (potentially high)** |
| **Passive Equipment Mounts (Vibration Isolators)** | Reduces surface-borne path noise | Difficult as a retro-fit;<br>Not effective for frequencies below 200 Hz for very large diesel engines due to large mass; requires dynamically stiff foundations | **High to very high** | **Low to Moderate** |
| **Dynamic (Active) Equipment Mounts** | Show significant promise; work well in other applications | Not widely available yet (still somewhat experimental) | **High to very high** | **Variable (potentially high)** |
| **Pump Isolations, Acoustic Filters, Pipe Hangers** | Pretty simple generally | Can be difficult as a retro-fit option | **Variable (potentially low)** | **Low to moderate** |
| **Acoustic Insulation** | Reduces AB & SB Transmission | More directed to minimizing aerial versus underwater noise | **Generally low [$1-$4/sq. ft]** | **Low to moderate** |
| **External and Internal Coatings (Dampening Products)** | Relatively simple | Effectiveness depends on material 'compliance' and thickness | **Generally low [$8-$12/sq. ft]** | **Low to moderate** |

***OPERATIONAL OPTIONS FOR VESSEL-QUIETING***

| **Treatment** | **Advantages** | **Disadvantages** | **ROUGH Cost Estimates (Low, Med, High)** | **Anticipated GENERAL Magnitude of Quieting (Low, Med, High)** |
|---|---|---|---|---|
| **Speed Reductions** | Appears to generally be one of the most promising ways to reduce vessel noise emission; should be some distinction between open-ocean and near-shore; Suggestion for some better routeing/scheduling around busy ports | Economically, politically, logistically very difficult; limited benefit on local scale more application on regional scale | **Variable (Potentially very high)** | **Variable (potentially high)** |
| **Routeing (Area Restrictions)** | Avoiding where animals are or operating in environments that do not favor long-range transmission | Economically, politically, logistically very difficult; Spatiotemporal aspects and environmental variability will prove challenging | **Variable (could be locally high)** | **Variable (could be locally high)** |

***

ANNEX 2

# MISCELLANEOUS BUT IMPORTANT ISSUES

## 50 Hz Predominance

1 In the last Correspondence Group Report, there was a discussion of the 50 Hz predominance. One participant stated that the cause of the 50 Hz noise contribution must be revealed and a solution for the reduction of this level should be found. Another participant stated that it seemed to have been agreed in the Group that it not pursue just the 50 Hz predominance. When I put this issue out for discussion in May 2009, I received the following comments:

.1 This issue is a very important point for the whole of this work…we are 'standing into danger' of 'putting the cart before the horse' … what environmental impacts are we trying to resolve by addressing shipping noise … it is no good putting forward engineering solutions when they may not be addressing an identified impact … or worse that we provide a solution at a single ship level only to find that when groups of ships are present the solution provided does not work … understanding in the nature of the impact to be addressed then sensible solutions that are effective can be offered up.

.2 The 50 Hz hump is only related to cavitation issues. Concerning all the different measures concerning noise reduction, this must be checked case by case and depending on some of the basic answers we are looking for.

Noise signature of propellers tends to consist of:

- very discrete tones attributed to blade rate;
- hulls; and
- true broad band (the latter two are often lumped into "cavitation").

Machinery Medium speed diesel 25 Hz up. Discrete tones.

3. There are two things involved in the 50Hz discussion: The broadband hump around 50Hz should remain in focus as this is one key issue for our goal. The 50Hz/60Hz components caused by the electrical mains should be excluded from the discussion, as a narrowband mechanical structural vibration of this frequency and a magnitude able to generate sufficient underwater noise has not been reported according to our knowledge.

4. It is strongly recommended to include the 50 Hz hump as a primary issue in the Correspondence Groups's work. It is the predominant feature of distant shipping noise, see e.g., Ross, D.G. (1976). Mechanics of Underwater Noise. Pergamon, New York, New York, 370 pp., Hatch et al 2008 or Andrew, R.K., Howe, B.M. & Mercer, J.A. (2002). Ocean ambient sound: comparing the 1960s with the 1990s for a receiver off the California coast. Acoustics Research Letters Online, 3, 65-70. The latter is the initiator of the discussion leading to foundation of this correspondence group.

5. The discussion about the 50 Hz includes a misunderstanding in connection with the 50 Hz mains on board some ships. The 50 Hz hump discussed here is caused by cavitation. One participant disagreed with this statement. If one only treats one source then what is achieved may only be a 3Db reduction, although the hump will the eliminated, what will be left is the platform of noise on which the hump will be super-imposed.

6. While it may be interesting to investigate the cause of the 50 Hz predominance, our focus should be on noise reduction for the 10 to 1000 Hz band.

2 So what is the way forward on this issue? It seems from the comments received lately that this issue only pertains to cavitation. Is a way forward that what we need to do in these guidelines is to give a number of noise control solutions that clients could ask of naval architects and shipbuilders? Please give me your opinion on this issue so that we can be clear about the way forward.

**Issues and IMO Committee and Subcommittees**

3 Are there issues being worked on by an IMO Committee or sub-committee or regulations or guidelines recently adopted where opportunities may exist for the introduction of the consideration of underwater noise? If so, how could we integrate such consideration? How would we manage a detailed understanding and integration with these other issues and still maintain a consistent and reasonable focus with regard to the overall issue of shipping noise? One participant stated that they felt that at this stage of our work we should not be considering these issues. Please provide your opinion on the questions posed.

4 Here are a few areas that might merit our further consideration. Please provide any thoughts you may have on how we may integrate our work into these issues.

.1 Design & Equipment Subcommittee is working on revising the Guidelines for ships operating in Arctic ice-covered waters.

.2 Is there a way to integrate a consideration of underwater noise? Annex VI was just revised and amendments adopted. Is there a way to integrate a consideration of underwater noise? One participant stated that they do not see a direct influence of the revised Annex VI to any kind of underwater noise.

.3 Greenhouse Gas Emissions – It was said repeatedly during the discussions of this issue at MEPC that there may be an impact on the noise issue. What is that impact?

.4 How can we integrate our work into the discussions?

One participant stated that the impact of the actual outcome of the GHG working group to underwater noise from ships can be seen in the requirement for more economical speed (meaning slow steaming) which might have a major influence on the underwater noise level of ships. This participant felt that this issue is already covered under the technological issues/speed reductions.

Another participant stated that one view that has been expressed in the Correspondence Group is that measures to improve fuel efficiency will be the same measures that offer the greatest promise for noise reduction. We should determine if this view is widely held. If yes, there is a connection of course to the GHG discussion. As a practical matter, it probably takes us back to the recommendations that may be best developed by the naval architecture community.

.5 Amendment of Annex V – Is there anything that might be applicable here? A few participants answered "No".

One participant agreed that Annex VI as it stands today is unlikely to be relevant, but that question is better answered when we see a set of peer-reviewed design recommendations and whether the GHG debate results in any amendments to Annex VI.

.6 DE's work on noise on board ships. One participant stated that if ships become more silent onboard, their underwater noise level might be lower as well; however, it should be considered that the propeller is not the dominant exciter for airborne noise in any case; on large container ships the airborne noise level is nearly independent from propeller effects. Another participant questioned why large container ships were singled out and queried whether it was related to noise associated with loading and unloading operations.

**Other Proposals Raised by Participants**

5 Please consider these proposals which are by two individual participants and no decisions have been taken on them by the Correspondence Group. What are your opinions on them? How, and should, the Correspondence Group integrate them into our future work? Are these points necessary to consider in the development of the guidelines?

**First Proposal**:

.1 Under the assumption that propeller noise is taken as the dominant noise source, this participant proposes to develop a simple tool based on an empirical or semi-empirical approach to estimate the sound power emitted by the propeller-wake interaction. This tool shall be used for both, ships in service and new builds, to predict/ reproduce the noise that can be or has been measured on one of the sound ranges.

.2 This participant stated that they would distinguish between following fixed and variable parameters to be considered in the approach:

Fixed:

.1 Design

- ship type
- hull form characteristics → wake characteristic
- definition of dominating load conditions
    - Tanker / Bulker: fully loaded or pure ballast
    - Container Ship: variable draught around a mean draught

.2 Propulsion system:

- Propeller diameter
- Propeller depth, propeller-hull clearance
- single screw/ twin screw
- fixed pitch propellers FPP / controllable pitch propellers CPP
- number of blades, shaft speed rpm
- pitch, skew
- propulsion power

Variable:

.3 Operating condition

- speed through water, reference speed $V_{\_ref}$ vs refence power $P_{ref}$ loading: draught (at aft perpendicular → propeller immersion), trim, heel, etc(?).

.3 This participant plans to combine available design data from ships under Germanisher Lloyd class with available test data for these ships at HSVA, as in the German mirror Correspondence Group there are competence and experts for ship design and operation, model basin tests, underwater noise and ship acoustics onboard ships.

.4 The participant stated that what we need is reliable UW noise data and any corresponding information from measurements of cargo ships to link those to our set of design parameters, model test results and full scale onboard-measurements, and finally to calibrate our rough empirical model approach. Preferably, these measurements are taken from the same one or two measurements ranges and allow the calculation of the standardised source level at 1m.

.5 To be successful in our simple approach, we have to be sure that one specific ship shows the same underwater-noise measurements values under similar operating conditions.

.6 We consider the studies to link UW-Noise to AIS data as the key to identify:

- the same ship ←→always same noise level?
- are there noisy types?
- are there noisy seasons ?
- or any other correlation ?

.7 The main purpose is to have a simple tool to be able to predict the impact of any technical measure we will discuss to decrease ships noise. Secondly, we gain a better understanding and can proceed in a more targeted way to apply all the big tools like numerical simulations and model basin tests.

**Second Proposal:**

.8 Since the propeller is assumed as the dominant noise source, this participant proposes the development of radiated sound prediction tools on advanced methodologies for the estimate of propeller noise (including the effects of propeller-wake and propeller-hull interactions). Such tools are able to account for the effect of main parameters of blade design and operation. An example for this is given by the development effort within the upcoming EDA project NAPNOP.

Of course, the high accuracy of results has a counterpart in the large computational burden. However, such tools may also be intended as a reference for the development of simplified procedures (for instance, to be implemented within numerical optimisation procedures), and a support for empirical procedures.

.9 Propeller/hull and propeller/rudder interactions are already addressed as a part of work programme of the EU FP7 project SILENV. Hull shape optimisation is a main subject of study at INSEAN since many years, and interaction with propeller is a challenging topic for those methodologies.

.10 An accurate modelling should guide the development of powerful prediction methods on both sides, sources and receptors. So, attention is to be paid to most work to the opportunity provided by joint work by marine biologists and mathematicians involved in the development of models for marine mammals hearing apparatus.

.11 This participant considers the possibility to link Underwater Noise characteristics to AIS data as a means to build models for the prediction of "noise footprints", similar to the tools for the study of environmental impact of airport areas.

***

# ANNEX 3

# WORK ON STANDARDS

There have been two groups that have been working on the development of standards pertinent to the issue of incidental underwater noise generated by commercial ships. Information on the work of these two groups is set out below.

## 1 International Standards Organization

ISO/TC8/SC2 Marine Environment Protection
Report of Exploratory Meeting on Underwater Noise Measurement Standard Development
Koichi Yoshida, Chairman of ISO/TC8/SC2

ISO/TC8/SC2 is now developing an ISO standard for measurement of underwater noise generated by merchant ships. The goal of the ISO standard would be to provide the method of determination of power level of the source of underwater sound emitted from ships and specification of measurement method and measuring instrument. ISO/TC8/SC2 met in July 2009 right after MEPC 59 and hold an exploratory meeting on this issue. Following is the report of the group.

The exploratory group met on 22 July 2009, and made discussion as follows:

- There was a general agreement to develop an International standard for measurement of underwater noise emitted from merchant ships;
- Measurement target is to obtain underwater noise source power of ships;
- Measuring equipment may be deployed by buoy or land-base, should be commercially feasible for merchant ship measurement, should be specified in the standard;
- Measurement conditions, e.g., background noise level and sea depth as well as measuring frequency band, should be taken into account;
- The condition of the target ship, e.g., draught, speed, engine operation, should be also taken into account;
- The concept of the standard is illustrated in the figure below;
- The group was informed that an ANSI activity will result in near future publication of **ANSI S 12.64** on almost the same subject. The SC2 chairman will contact with the ANSI group and its chair person;
- After the consultation with ANSI, SC2 chairman will develop the next draft by the end of October and circulate it to the members of the exploratory group, aiming to developing an ISO standard;
- The exploratory group should meet in conjunction with the next SC2 plenary meeting toward starting the new work item; and
- SC2 is invited to inform the progress to IMO MEPC and its correspondence group on underwater noise.

## 2 The American National Standards Institute (ANSI)

**ANSI S12.64**

AMERICAN NATIONAL STANDARD
**Quantities and Procedures for Description and Measurement of Underwater Sound from Ships -**

**Part 1: General Requirements**

The American National Standards Institute is developing a standard for the measurement of underwater sound associated with vessels. This standard describes the measurement systems, procedures, and methodologies used for the beam aspect measurement of underwater sound pressure levels from ships for a given operating condition. The resulting quantities are reported as nominal source level values. It does not require the use of a specific ocean location, but the requirements for an ocean test site are provided. The underwater sound pressure level measurements are performed in the far-field and then corrected to a reference distance of 1 m. This standard is applicable to any and all surface vessels either manned or unmanned. This standard is not applicable to submerged vessels or to aircraft. Measurement systems are described for measurement of underwater sound pressure levels and also the distance or range between the underwater transducers and subject vessel. Processing and reporting of the data are described and informational guidance is provided. This standard does not specify or provide guidance on underwater noise criteria.

The standard was approved in May 12, 2009 and should be issued by the end of 2009.

Chair, S12/WG47 M. Bahtiarian
Noise Control Engineering, Inc.
799 Middlesex Turnpike
Billerica MA 01821 Email
Phone 978-670-5339
978-667-7047
mikeb@noise-control.com

***

**ANNEX 4**

**RESEARCH NEEDS**

There is a need for more research in this area and that any such work should be done simultaneously with the work of our IMO Noise Reduction Team. The below list represents suggestions from Correspondence Group members. Additionally, Correspondence Group participants were asked to identify any facilities where research on the issue of underwater noise from commercial shipping is being done or could be done. Participants were also asked to note whether such facilities would have any associated issues related to national security or access to information.

1 One participant suggested that the relationship of the magnitude of radiated noise due to propeller cavitation and vessel speed should be measured, using appropriate metrics and reporting standards measured. It was felt that this will need to be undertaken on instrumented ranges to ensure comparisons can be made by ships measured in differing parts of the world. The noise ranges must work with the same methodologies. Another participant, in responding to the latest round of comments, noted that there is currently a lot of work being done in this area. They suggested that it would be more useful to direct additional work towards predicting propeller noise at the design stage.

2 Another participant suggested that the relationships between propeller pitch settings, propeller loading, and other propeller design parameters also need to be measured with respect to underwater radiated noise for different vessel categories. One participant felt that the noise range must encompass all possible engineering options such as speed and pitch.

3 Another participant raised the issue of active mounting systems: Today, these can be considered proven and commercially available but not universally used to quiet ships, even for military applications. These might be helpful in certain special applications in commercial ships but some additional research is required, and careful consideration given to the cost/benefit of implementing and maintaining the efficiency of such approaches relative to other possible treatments (esp. those in the propulsion systems). One participant stated that the requirement to use this technology is only limited because of supposed cost and that there is no legal requirement to use it although if this were to change then it was thought that there would be greater use of such technology. Another participant, in response to the last round of questions from the Correspondence Group, stated that they thought active mounting systems were still at the concept/prototype stage in military applications. They suggested that the focus should be on exhaust quieting options for passive mounts first.

4 Another participant raised the 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 Automatic Identification System (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 (and correction to table)* 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.
- Another participant stated that understanding and record of the environmental parameters is required to ensure that comparisons of noise classification can be made. Yet another participant suggested that information as to the impact of the environmental noise, such as wave action, water current and other noise than that generated from the vessel, and how these noise sources can be isolated to obtain the noise generated by the vessel. Moreover, we should look at the impact of water temperature, density, etc., on the noise measurement and how the measured data can be normalized.
- Another participant recommended limiting the discussion on measuring standards and field measurements to concentrate on measures for individual ships.
- Another participant 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: 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).
- One participant stated that 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. It was noted by another participant that there are commercial organizations such as QinetiQ that run fully instrumented noise ranges on behalf of the military and are allowed to sell spare capacity on the range for commercial purposes. The signal processing and range design are quite important to achieve a successful signature recording.
- 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 Long Range Identification and Tracking (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.

- Another participant noted that there are two types of noise monitoring required:

  .1 to establish a ships signature – which is best done on a purpose built range; and

  .2 to enforce any legal requirements for noise reduction which requires a completely different capability and could be done using the limited hydrophones available supplemented with systems being put in place in MPA.

- Another participant stated that these ideas are sound but again raised 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? One response to these questions stated that the accuracy required will be dictated by the severity and range of impacts experienced by the receptor—current impact criteria do not have a sensitivity dimension.
- Another participant, in response to the latest round of questions from the Correspondence Group, stated that measurement should be of individual ships. This can be done on a noise range. Alternatively, measurements of opportunity are possible using sonar buoys or hydrophones and this should be done where background noise is minimal. They stated that noise that one is trying to measure needs to be 10 db above background. Additionally, this participant noted that calibrated measurement systems to environmental parameters of location (e.g., water depth) is needed.
- Another participant agreed that it was very important to correlate measures of generated sound with general information on the ship characteristics and general information concerning the mission, for single ship study, as well as forecast of ship traffic effect.
- Another participant agreed that research should correlate measures of generated sound with general information on the ship characteristics and its mission, for a single ship study, as well as forecast of ship traffic effect.
- Yet another participant stated that it should be made clear that it is necessary to understand the characteristics of an individual ship in a known configuration, measured on the beam aspect, and at a known distance so that representative source levels can be generated by correcting back to 1 m. Seabed hydrophones and other methods can give an understanding of the noise levels in an area, and the statistical variability with the time and season, etc., but not the characteristics of individual ships. The variable distances, differences in propagation loss, the vertical directivity of the ship radiated noise and the unknown ship state prevent the determination of individual ship noise levels.

5 One participant stated that there should be a study of 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 by this participant that the impact of noise must be known to determine the most important noise sources.

6 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 (Note: "medium" and "low" speed engines may require further definition as we go forward; however, one participant stated that the definition of low and medium speed engines are as follows: Medium speed engines are 4-stroke-cycle diesel engines either driving a propeller via a reduction gear (300 to 600 rpm) or a generator (600-900 rpm). A low speed engine is a 2-stroke-cycle diesel engine directly driving the propeller (60-150 rpm). In shipbuilding, this difference is quite clear). This participant felt that 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). One participant disagreed with this stating that noise reduction measures must be determined by the impact made on the receptors present. There could be a highly sensitive receptor still being impaired by a quiet ship if the environmental circumstances were right.

- One participant agreed with the need to base noise reduction measures on the knowledge of the impact made on receptors. This implies that most of the research work on technological aspects should be strongly linked to research achievement on the biological side to understand reception mechanisms and subsequent effects on receptors. An accurate mathematical modelling may be helpful in the development of a powerful prediction methods on both sides.

7 Another participant felt that investigations into propeller-induced radiated noise of commercial vessels should be extended and supported by further research. One participant thought that this should not be done before an exhaustive literature review is undertaken to understand where the gaps in knowledge are.

8 One participant stated that we need (1) to correlate measured noise data and observed cavitation phenomena; (2) to correlate cavitation phenomena and geometrical design counter measures, therefore detailed numerical and experimental investigations have to be foreseen; (3) detailed full scale measurements and that the frequencies contributing to the noise have to checked carefully; (4) to check if onboard measurements can give us the answers we need; and (5) to combine model tests and numerical calculations. This participant noted that noise measurement can be done at Hamburg Ship Model Basin (Hamburgische Schiffbau-Versuchsanstalt), SSPA Sweden AB, MARIN (Maritime Research Institute Netherlands) and the David Taylor Model Basin.

9 One participant noted that we still have to identify ship types with the most urgent need for noise reduction. Therefore in order to measure and classify ship noise levels, we should be able to cluster ship types, including machinery or loading conditions, to establish the correlation to their acoustic signature. If we do not follow this approach, we will be acting only on assumptions and not on tangible facts. All measurement campaigns on individual ships are often either inconsistent in themselves or not comparable with each other. Another participant felt that in addition to propeller design and other information listed, the following information should be collected: vessel characteristics, draft/trim of the vessel, loading conditions, propeller type: fixed vs. CRP, propeller RPM, and hull & propeller condition.

- This participant also noted that there is still a need for proven data and apportionment for the overall noise emitted by a cargo ship: there is still no clear evidence of how much of the sound power is emitted by which part of the ship or by which phenomenon, and in which frequency range dominates which effect. This participant stated that it is not always the propeller that is responsible for the total noise. As long as there is no clear distinction which amount of noise is radiated via the hull, research is needed to identify the governing mechanism and potential contribution to the total sound power emitted by the ship.

10 Another participant stated that it is of great importance to investigate propeller designs for a better compromise between efficiency and radiated noise, particularly for controllable pitch propellers. Yet another participant stated that for propellers, beside cavitation (which undoubtedly is a major noise source), we should be able to predict cavitation noise as well as the inherent pressure pulses/fluctuation, that may be potentially reflected by the ship's hull and radiated into the water. Here the methods of computational fluid dynamics (CFD) should support the model basin effort:

- Verification: This participant would appreciate the development of specific standards for measuring underwater noise. However, it was noted that it would be hard to imagine measuring every type of ship, including new builds and retrofits, so we should decide how to provide a "silent ship":

  -by design/calculation

  -by onboard measurements (structureborne sound, pressure fluctuations) during sea trial, or

  -by real hydrophone measurements—this was deemed critical for verification purposes.

- Another participant stated in this round of comments that a verification approach should be prepared that is commonly accepted and meaningful.

11 One participant stated that it is necessary to strictly observe the frequencies of noise contributions. It is recommended to concentrate on long range (for example > 10 nm) effects where the shipping frequency spectrum dominates over primordial levels below 300 Hz.

12 One participant noted the following polar issues should be areas for priority research:

- Research on the Arctic - One of the key issues about ship noise in the Arctic below 1kHz, is that ocean acidification has, in the past five years, greatly increased the transmissivity of the ocean in the upper water column (where the sound channel is in the Arctic) to sound in this range. Coverage of the Arctic, especially around Alaska, is not well-documented. This suggests that in the future, if this is where the change is greatest, this is where ship noise reduction efforts should be focused, particularly because this is also the communication frequency range of the great whales.

- Research on Azipods – This participant felt that there should be further review of azipods to better understand when, how, and whether noise reduction from these takes place. Because in the Arctic the sound channel is in the upper water column, and new icebreakers and ice strengthened commercial vessels are using azipods, more information on this topic is among the most critical research needs that should be identified in this report. It is possible that the newer icebreaking ships, which have azipod engines, have a more linear, less disturbed flow around the props, and are thus both less noisy, and more efficient for propulsion as well. The new icebreaking cargo ships being built have just such propulsion systems.

- Research on ship loading – Some icebreakers can have very different loads, mostly of fuel, depending on time during operation (e.g., in McMurdo Sound area full of fuel at beginning of season, not so much at end). More study on what ships, or what loading levels/variation effects on noise are would be useful.

- Research for prop depth – Icebreaker props are fairly deep: 33.5 feet down already. This is in part to avoid ice. In building a new ship, is it possible to make them deeper and would this result in them being quieter?

- Research for retractable keels – Some of the newer research ships, including icebreakers, have retractable keels. The keels are raised in ice, but lowered in open water to reduce ship roll due to rounded hull design required for optimal icebreaking. Does a retractable keel reduce noise due to ship roll significantly? Is the sound reduction only due to roll reduction effects on water moving around the hull or is it more due to water movement increased laminar flow around the props?

13 One participant asked whether there is a potential for noise reduction by getting away from controllable pitch propellers such as electric (i.e., diesel generators) drives fixed pitch propeller. This participant stated that this is like pods but perhaps they can be put onboard and then isolated. Generally the luxury cruise liner industry does this for minimizing sound onboard, so there is already technology in use on liners and military vessels. Research may be necessary to determine how underwater radiated noise rather than onboard noise can be reduced.

14 The following research facilities were identified as places where research is being done or could be done on the issue of underwater noise from commercial shipping:

- Hamburg Ship Model Basin (Hamburgische Schiffbau-Versuchsanstalt);
- SSPA Sweden AB;
- MARIN (Maritime Research Institute Netherlands);
- David Taylor Model Basin;
- Australian Maritime Hydrodynamics Research Centre http://www.amhrc.edu.au/ - Collaborative research centre of the Defense Science and Technology Organization, the Australian Maritime College and the University of Tasmania. Range of hydrodynamic research supported by infrastructure including cavitation tunnel, towing tank, integrated marine simulator (shiphandling and ship operations), flume tank, model test basin and high performance computer network;
- Vipac - http://www.vipac.com.au/marine.html - Commercial consultants providing design analysis and sea trial services in the areas of vibration and acoustics and underwater radiated noise;
- University of New South Wales (Mechanical Engineering, Vibration and Acoustics Research Group) – Work on selected aspects of radiated noise;

- QinetiQ – Maritime signature support from initial design and model testing through to acoustic ranging of all in service platforms deployed worldwide and at fixed ranges in the UK. Includes full signature decomposition and analysis and presentation to the customer in an easy to understand informative format;
- British Aerospace;
- BBN (US);
- Lloyds Register ODS – luxury liner noise work;
- INSEAN, the Italian Ship Model Basin; and
- See also annex 5.

15 One participant reiterated their comments stating that we need to go further on the following items:

- Measurement and classification of ship noise levels, link to AIS and ship design/operation data;
- Clarifying the governing phenomena; and
- Preparing a verification approach that is commonly accepted and meaningful.

16 Another participant identified the following main topics where significant research should occur:

- to correlate measures of generated sound with general information on the ship characteristics and its mission, for single ship study, as well as forecast of ship traffic effect;
- Noise reduction measures should be based on the knowledge of the impact made on receptors. This implies that most of the research work on technological aspects should be strongly linked to research achievement on the biological side to understand reception mechanisms and subsequent effects on receptors; and
- Prepare a verification approach that is commonly accepted and meaningful.

17 Another participant stated that they felt that this document on research needs contains useful information on ship noise measurements but some of the apparent differences of opinion relate to different assumptions about the trade offs between absolute accuracy, relative precision and number of ships measured. At one end of the scale, dedicated noise measurement ranges can make very accurate absolute measurements but only of a limited number of vessels. At the other extreme, bottom mounted hydrophones together with AIS have the potential to collect measurements from a large number of vessels but with much lower accuracy.

- This participant continued, saying that for some purposes a set of relative measurements of a number of vessels may be adequate, recognizing that these may not be directly comparable with measurements from other areas. As more data become available from the different types of measurement systems there will be a need for an assessment of the most appropriate methodology to address specific questions taking into account achievable sample sizes, accuracy and precision. These assessments will be assisted by experiments involving simultaneous measurements using different systems.

18 Finally one participant indicated that particular emphasis should be shown for research and studies focused on demonstrating the efficiencies and operational cost savings that are achievable through the use propellers designed to reduce radiated noise.

***

**ANNEX 5**

**MODEL BASINS**

| Model Basins | | | | |
|---|---|---|---|---|
| **Country** | **Contact** | **Association** | **E-mail** | **Web Site** |
| Australia | Prof. Neil Bose | Australian Maritime College Ship Hydrodynamics Centre | n.bose@amc.edu.au | http://www.amc.edu.au |
| Austria | Prof. Gerhard Strasser | Vienna Model Basin | gerhard.strasser@sva.at | http://www.sva.at/ |
| Belgium | | Ministry of the Flemish Community Flanders Hydraulic Laboratory | | |
| Brazil | Dr. Carlos Daher Padovezi | Instituto de Pesquisas Technologicas do Estado de Sao | padnaval@ipt.br | http://www.ipt.br/ |
| Bulgaria | Dr. Kostadin Yossifov | Bulgarian Ship Hydrodynamics Centre(DSHC), | k.yossifov@bshc.bg | http://www.bshc.bg/ |
| Canada | | Fleet Technology, Ltd. | | |
| Canada | Dr. F. Mary Williams | Institute for Marine Dynamics (NRC) | fmary.williams@nrc-cnrc.gc.ca | http://iot-ito.nrc-cnrc.gc.ca |
| Canada | | Faculty of Engineering and Applied Science Ocean Engineering Research Centre, | | |
| China | Prof. Zhenping Weng | China Ship Scientific Research Center (CSSRC) | wengzp@cssrc.com.cn | http://www.cssrc.com.cn/ |
| China | Prof. Zhi Zong | Dalian University of Technology Research Institute of Naval Architecture | zongzhi@dlut.edu.cn | http://www.dlut.edu.cn/ |
| China | Dr. Xiongliang Yao | Harbin Shipbuilding Engineering InstituteDepartment of Naval Architecture and Ocean Engineering, | heu-yxl@163.com | http://www.hrbeu.edu.cn/ |
| China | Prof. Yao Zhao | Huazhong University of Science and Technology(HUST) | yzhaozzz@hust.edu.cn | http://www.hust.edu.cn |

| | | | | |
|---|---|---|---|---|
| China | Prof Sheming Fan | Marine Design and Research Institute of China (MARIC) | samfan@public4.sta.net.cn | http://www.maric.com.cn |
| China | Prof. Jianming Yang | Shanghai Jiao Tong University Ship Hydrodynamic Laboratory | jmyang@sjtu.edu.cn | http://www.sjtu.edu.cn/ |
| China | Prof. Xiaping Chen | Shanghai Ship and Shipping Research Institute(SSSRI) Ministry of Communications | srd@sssri.com or xpchen603@sina.com | http://www.sssri.com/ |
| China | Dr. Xiaofei Mao | Wuhan University of Water Transportation Engineering Ship Hydrodynamics Laboratory | mxfzh@163.com | http://www.whut.edu.cn/ |
| China | | Tianjin University Ocean and Ship Engineering Department | | |
| Croatia | Mr. Zeljko Djigas | Brodarski Institute | zeljko.djigas@hrbi.hr | http://www.hrbi.hr/ |
| Denmark | Dr. Stig Sand | Danish Maritime Institute | ss@force.dk | http://www.force.dk |
| Finland | Prof. Jerzy Matusiak | Ship Hydrodynamics Laboratory | Jerzy.Matusiak@tkk.fi | http://www.tkk.fi/Units/Ship |
| Finland | | Wartsila Icebreaking Model Basin | | |
| France | Dr. Christian Hélou | Bassin D'Essais des Carenes | christian.helou@dga.defence.gouv.fr | http://www.bassin.fr/ |
| France | | Centre D'Essais Aeronautique de Toulouse (CEAT) | | |
| Germany | Dipl.-Ing. Juergen Friesch | Hamburgische Schiffbau-Versuchsanstalt GmbH | Friesch@hsva.de | http://www.hsva.de/ |
| Germany | Dr. Manfred Mehmel | Schiffbau-Versuchsanstalt Potsdam GmbH | mehmel@sva-potsdam.de | http://www.sva-potsdam.de/ |
| Germany | | Technische Universitaet Tostock Fachbereich Maschinenbau und Schiffstechnik | | |

| | | | | |
|---|---|---|---|---|
| Germany | | Sektion Schiffstechni Wilhelm Pieck Universitaet, Rostock | | |
| India | | Indian Institute of Technology Department of Naval Architecture | | |
| India | Dr V. Bhujanga Rao | Ship Research Division | director.nstl@gov.in | http://www.drdo.org/labs/nstl/index.html |
| India | | Government of India Central Water and Power Research Station | | |
| Indonesia | Dr. Ir. Samudro | Faculty of Marine Technology – ITS Hydrodynamics Laboratory | samudro@ceo.bppt.go.id | www.indonesian-hydrolab.com |
| Indonesia | | Indonesian Hydrodynamic Laboratory Surabaya (LHI) | | |
| Italy | Prof. Carlo Podenzana-Bonvino | Istituto Policattedra di Ingegneria Navale | podenzana@dinav.unige.it | http://www.dinav.unige.it/ |
| Italy | Dr. Daniele Ranocchia | INSEAN | d.ranocchia@insean.it | http://www.insean.it/ |
| Japan | Dr. Yasunroi Iwasaki | Akashi Ship Model Basin Co., Ltd. | iwasaki_y@asmb.co.jp | http://www.asmb.co.jp |
| Japan | Mr. Toshikazu Masuya | Fishing Boat and Instrument Division National Research Institute of Fisheries Engineering | masuya@affrc.go.jp | http://nrife.fra.affrc.go.jp/ |
| Japan | | Hiratsuka Research Laboratories Fluid Dynamics Engineering Section Sumitomo Heavy Industries, Ltd. | | |
| Japan | Prof. Yasuuki Doi | Hiroshima University, Faculty of Engineering Department of Naval Architecture and Ocean Engineering | doi@naoe.hiroshima-u.ac.jp | http://www.naoe.hiroshima-u.ac.jp/ |

| | | | | |
|---|---|---|---|---|
| Japan | Prof. Jun Ando | Kyushu University Department of Naval Architecture | ando@nams.kyushu-u.ac.jp | http://www.nams.kyushu-u.ac.jp/ |
| Japan | Dr. Kazuyuki Yamakita | Meguro Model Basin The First Research Center The Technical Research and Development Institute Defense Agency | ymkt@cs.trdi.mod.go.jp | http://cs.trdi.mod.go.jp/ |
| Japan | Mr. Chiharu Kawakita | Mitsubishi Heavy Industries, Ltd. Nagasaki R & D Center Nagasaki Experimental Tank | chiharu_kawakita@mhi.co.jp | http://www.mhi.co.jp/ngsrdc/english/senpaku/senpaku_top.html |
| Japan | Dr. Norio Ishii | Mitsui Engineering and Shipbuilding Co., Ltd. Akishima Laboratory | ishiin@ak.mes.co.jp | http://www.mes.co.jp/Akiken/index-j.html |
| Japan | Prof. Yasuyuki Toda | Osaka University Department of Naval Architecture and Ocean Engineering | toda@naoe.eng.osaka-u.ac.jp | http://www.naoe.eng.osaka-u.ac.jp/ |
| Japan | | Research Institute Ishikawajima-Harima Heavy Industries, Co., Ltd. | | |
| Japan | | Research Institute for Applied Mechanics Tsuyazaki Sea Safety Research Laboratory Kyushu University | | |
| Japan | | Ship Research Institute Ministry of Transport | | |
| Japan | Dr. Kazunori Sato | Shipbuilding Research Center of Japan | k_sato@srcj.or.jp | http://www.srcj.or.jp/ |
| Japan | | Tsu Laboratories, NKK Co., Ltd. | | |
| Japan | Prof. Yoshiho Ikeda | University of Osaka Prefecture Department of Naval Architecture College of Engineering | ikeda@marine.osakafu-u.ac.jp | http://www.marine.osakafu-u.ac.jp/ |
| Japan | | University of Tokyo Department of Naval Architecture and Ocean Engineering Faculty of Engineering | | |

| | | | | |
|---|---|---|---|---|
| Japan | Prof. Tsugukiyo Hirayama | Yokohama National University Department of Naval Architecture and Ocean Engineering | hirayama@seawolf.shp.ynu.ac.jp | http://www.ynu.ac.jp/ |
| Japan | Dr. Chaniku Shin | Nagasaki Institute of Applied Sciences | shin@ship.nias.ac.jp | http://www.nias.ac.jp/ |
| Japan | | Institute of Marine Science and Technology Faculty of Mercantile Marine Science | | |
| Japan | Prof. Eiichi Kobayashi | Faculty of Mercantile Marine Science | kobayasi@maritime.kobe-u.ac.jp | http://www.maritime.kobe-u.ac.jp/ |
| Korea | Dr. Hong-Gi Lee | Hyundai Maritime Research Institute (HMRI) | hglee@hhi.co.kr | http://www.hhi.co.kr/ |
| Korea | Prof. Young-Gill Lee | INHA university Towing Tank Department of Naval Architecture and Ocean Engineering | younglee@inha.ac.kr | http://www.naoe.inha.ac.kr/ |
| Korea | | Korea Research Institute of Ships and Ocean engineering (KRISO) | | |
| Korea | Prof. Ho-Hwan Chun | Pusan National University, Department of Naval Architecture | chunahh@pusan.ac.kr | http://www.pusan.ac.kr/ |
| Korea | Prof. Key Pyo Rhee | Seoul National University Department of Naval Architecture | kprhee@snu.ac.kr | http://naoe3.snu.ac.kr |
| Korea | | Advanced Fluid Engineering Research Center Department of Mechanical Engineering, POSTECH | | |
| Korea | | Chungnam National University Department of Naval Architecture and Ocean Engineering College of Engineering | | |

| | | | | |
|---|---|---|---|---|
| Korea | Dr. Seung-Myun Hwangbo | Samsung Ship Model Basin (SSMB) | s.hwangbo@samsung.com | http://www.shi.samsung.co.kr/ |
| Malasia | | Marvic Technology Laboratory | | |
| Netherlands | Prof.ir. J.J. Hopman | Delft Ship Hydromechanics Laboratory | J.J.Hopman@tudelft.nl | http://www.3me.tudelft.nl/ |
| Netherlands | Ir. A.H.Hubregtse | Maritime Research Institute Netherlands (MARIN) | management@marin.nl | http://www.marin.nl/ |
| Norway | Dr. Carl Trygve Stansberg | MARINTEK | Carl.T.Stansberg@marintek.sintef.no | http://www.marintek.sintef.no/ |
| Poland | Dr. Leszek Wilczynski | Ship Hydromechanics Division | modbas@cto.gda.pl | http://www.cto.gda.pl/ |
| Russia | Dr. A.V. Pustoshny | Krylov Shipbuilding Research Institute | krylov@krylov.spb.ru | http://www.krylov.com.ru |
| Spain | Adm. José M Sevilla | Canal de Experiencias Hidrodinamicas De EI Pardo | jmsevilla@cehipar.es | http://www.cehipar.es/ |
| Sweden | Ms Susanne Abrahamsson | Swedish Maritime Research Centre SSPA Maritime Consulting AB | susanne.abrahamsson@sspa.se | http://www.sspa.se/ |
| Turkey | | Ata Nutku Ship Model Testing Laboratory | | |
| UK | | Experimental and Electronic Laboratories | | |
| UK | | University of Glasgow | | |
| UK | Prof. Atilla Incecik | University of Strathclyde Department of Ship Marine Technology | atilla.incecik@na-me.ac.uk | http://www.na-me.ac.uk |
| UK | | QinetiQ Haslar | | |
| UK | Prof. Mehmet Atlar | Department of Naval Architecture and Shipbuilding | mehmet.atlar@ncl.ac.uk | http://www.marinetech.ncl.ac.uk/ |
| UK | | Vosper Thornycroft (UK) Ltd. | | |
| UK | Prof. W.G. Price | Department of Ship Science | w.g.price@soton.ac.uk | http://www.ses.soton.ac.uk/ |

| | | | | |
|---|---|---|---|---|
| USA | Dr. William C. Zierke | The Pennsylvania State University Applied Research Laboratory Fluid Dynamics Department | wcz1@only.arl.psu.edu | http://www.arl.psu.edu/ |
| USA | | The Offshore Model Basin (Formerly Arctec Offshore Corporation) | | |
| USA | Dr. Stuart Jessup | David Taylor Model Basin Carderock Division NSWC | stuart.jessup@navy.mil | http://www.dt.navy.mil/ |
| USA | Dr. Raju Datla | Stevens Institute of Technology Davidson Laboratory | rdatla@stevens.edu | http://www.stevens.edu/engineering/cms |
| USA | | Hydronautics Research, Inc | | |
| USA | Prof. Frederick Stern | The University of lowa Lowa Institute of Hydraulic Research | frederick-stern@uiowa.edu | http://www.iihr.uiowa.edu/ |
| USA | | Massachusetts Institute of Technology Cambridge Ocean engineering Testing Tank | | |
| USA | | Offshore Technology Research Center | | |
| USA | Prof. Robert F. Beck | The University of Michigan Ship Hydrodynamics Laboratory | rbeck@engin.umich.edu | http://www.engin.umich.edu/dept/name |
| USA | Prof. Robert G. Latorre | The University of New Orleans School of Naval Architecture and Marine Engineering | rlatorre@uno.edu | http://www.uno.edu/~engr/towtank |
| USA | | US Army Cold Regions Research and Engineering Laboratory | | |
| USA | Prof. G. J. White | U.S. Naval Academy Hydromechanics Laboratory | greg@usna.edu | http://usna.edu/Hydromechanics |
| USA | | University of California Department of Naval Architecture and Offshore Engineering | | |

**UNITED STATES DEPARTMENT OF COMMERCE**
**National Oceanic and Atmospheric Administration**

October 6, 2009

Dear Sir or Madam:

The United Nations' International Maritime Organization (IMO), under its Marine Environment Protection Committee (MEPC), has recently formed a correspondence group (CG) to address the issue of incidental underwater noise from commercial shipping and its potential impacts on marine life. This has been identified as an issue of high priority within MEPC. This international CG comprised of scientists, engineers, industry representatives, managers, and conservation groups, is tasked with *identifying* and *addressing* means of reducing the incidental introduction of noise from commercial shipping operations into the marine environment. Our goal is to develop practical, effective guidance on viable technical solutions to reduce the levels of underwater noise produced by transiting commercial ships. As you can see from our attached report from April (2009), we have considered this issue in considerable detail and have benefited from the input of subject-matter experts. From these deliberations, it is obvious that this is a large and complex issue, but one in which there seems to be some promise of success in certain areas. We have concluded that the most appropriate initial efforts should focus on means to reduce propeller cavitation for various classes of commercial vessels, with particular emphasis on low-frequency (less than 300 Hertz [Hz]) underwater radiated noise.

To proceed with the goals of the CG, we are now seeking the expertise of those directly involved with ship design and development. We are aware that some aspects of ship performance are optimized prior to building by undergoing thorough evaluations at model basins. While we further understand that propeller performance and hull design play key roles in model basin work, we are unclear as to whether radiated noise resulting from different design configurations are explicitly measured during optimization trials. This letter seeks clarification as to whether your facility collects data in connection with noise and vibration prediction associated with model trials, and, if so, how these data are used to optimize ship designs. In particular, we are interested in any empirical information that you could provide that would assist the CG in quantifying potential reductions in cavitation and thus low-frequency acoustic emissions (<300 Hz) resulting from optimizing propeller, hull, or other ship features. Is it possible to extend your prediction abilities to the frequency range <1000 Hz with your current equipment? Further, will any of these reductions be expected to result in any increase in fuel efficiency or reduction in greenhouse gas emissions or have other technical or economical advantages and disadvantages?

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration

If your facility has identified design features that are likely to or known to reduce incidental noise production in final builds, it would be greatly appreciated if you would be willing to share this knowledge with us to report back to the CG. We fully understand that the proprietary nature of some data would need to be taken into consideration. Our first goal, in opening this dialog, is to better understand how extensively underwater incidental noise production is currently being evaluated when designing new builds for different commercial ship types, and whether model basins could provide suggestions for ways to evaluate the acoustic consequences of designing ships with better fuel economy and/or higher emission standards.

Thank you in advance for your time, consideration, and feedback.

Sincerely,

Amy R. Scholik-Schlomer

Amy R. Scholik-Schlomer, Ph.D.
Fishery Biologist
NOAA's National Marine Fisheries Service, Office of Protected Resources
1315 East-West Highway
SSMC III, Room 13605
Silver Spring, Maryland 20910
U.S.A.
Tel: (301) 713-2322 x167
Fax: (301) 713-4060
Email: Amy.Scholik@noaa.gov

Leila T Hatch

Leila T. Hatch, Ph.D.
Marine Ecologist
NOAA's National Ocean Service
Stellwagen Bank National Marine Sanctuary
175 Edward Foster Road
Scituate, Massachusetts 02066
U.S.A.
Tel: (781) 545-8026 x203
Fax: (781) 545-8036
Email: Leila.Hatch@noaa.gov

Attachment:
MEPC 59/19 Report of the Correspondence Group

**SUMMARY of MODEL BASIN responses to IMO Correspondence Group on Vessel Quieting request for information**

**Overview/Chronology**

Members of the United States contingent of the IMO Correspondence Group on Vessel Quieting developed a written request for information to model basins and other research and technological facilities regarding technical information on vessel quieting technologies. Specifically, this letter asked for information regarding quantification of low-frequency noise reduction from optimizing propeller, hull or other designs, as well as any information related to increased efficiency or reduced emissions. This letter, sent and co-signed by Drs. Leila Hatch and Amy Scholik-Schlomer (from the U.S. National Oceanic and Atmospheric Administration), was sent on 6 October 2009 to 90 scientists or R&D facilities in 26 nations.

As of 24 November 2009, a total of six responses have been received in response to this request for information, four of which include substantive technical information. Generally, these responses were supportive and consistent with the report of the Correspondence Group from MEPC 59 (MEPC 59/19) which was attached to the transmission letter. The below table summarizes these responses, which are provided in their entirety in the subsequent section. Some of the most important points raised in the four substantive responses include the following:

- Structural vibration induced by propeller movement (causing stern plates to resonate as a function of limited clearance from prop blades) and other on-board machinery is an important consideration in engineering efforts to reduce radiated noise.

- The difficulty was noted for many test facilities to accurately assess low frequency radiated noise, where it is considered and assessed, because of high ambient noise (within the testing enclosures) at low frequencies; this masks accurate measurements.

- Design features for cavitation noise reduction are numerous and can be subdivided into (1) hull line design; (2) appendage design; (3) propeller design; and (4) retro-fits.

- Researchers in the Netherlands have observed a 50 Hz maximum in hull pressure fluctuations resulting from propeller-induced vortices; this may be related to the “hump” seen in the radiated noise spectrum at this frequency.

- Optimal design of propellers from a quieting perspective is slow moving, large-diameter, non-cavitating propeller with many blades (with reduced propeller loading, though this decreases efficiency) in a uniform flow; obviously there are practical and engineering limits to this.

- Optimum propeller design is usually a trade-off between efficiency and cavitation performance; high efficiency and thus low fuel consumption has usually the highest priority among commercial ship-owners.

- Optimizing hull design can both increase the hull efficiency and achieve a smoother wake field (inflow) which gives the propeller better acoustic performance, although load carrying capacity, port and fairway restrictions can be limiting.

## TABLE OF RESPONSES AND SIMPLE SUMMARY OF CONTENT

| Responder (Organization) | Date Received | SIMPLE SUMMARY |
|---|---|---|
| **Robert Beck** (Naval Architecture and Marine Engineering; University of Michigan) | **7 Oct 09** | Nothing substantive in this response. Dr. Beck just indicates that he has forwarded the request for information to Prof. Nick Vlahopoulos, who is "the department's expert on acoustics". Dr. Vlahopoulos has yet to follow up with a response. |
| **Z. Zong** (Towing Tank of Dalian University of Technology, China) | **8 Oct 09** | Dr. Zong leads the towing tank of Dalian University in China, which measures shipborn vibration and noise, as well as underwater acoustics (radiated noise). He essentially agrees with the conclusions of the report and of the focus of the correspondence group on cavitation. However, he also notes that another design issue that is often overlooked is the relatively little clearance allowed between the propeller and the hull of the stern. He indicates that this can cause resonance of the structural plates of the stern, resulting in significant radiated underwater noise. Structural vibration induced by propeller and machinery noise is an important consideration in engineering efforts to reduce radiated noise. |
| **Mary Williams** (NRC Institute for Ocean Technology) | **9 Oct 09** | Nothing substantive in this response. It just indicates that NRC-IOT does not have expertise or experience in the field of vessel quieting. Subsequent transmissions could exclude them from inclusion. |
| **Johan Bosschers** (Research and Development, MARIN, Netherlands) | **28 Oct 09** | This group in the Netherlands (MARIN) is involved in several projects directly related to the IMO Correspondence Group, specifically far-field radiated propeller cavitation noise and broadband hull pressure fluctuations generated by cavitating propeller vortices. They confirm that noise is not considered in the design process for most vessels. They also note the difficulty in many test facilities to accurately assess low-frequency radiated noise and that there is significant energy in radiated noise and hull pressure fluctuations at higher frequencies (> 1 kHz). Like Dr. Zong, they also note the importance of considering hull vibration and resonance from propeller motion; they have observed a 50 Hz maximum in hull pressure fluctuations which may be related to the "hump" seen in the radiated noise spectrum. They indicate that there is a non-liner relationship between hull pressure fluctuations and far-field radiated noise, and that some information exists (seems classified or proprietary) on the relation between (non-uniform) ship wake fields, propeller geometries and hull pressure fluctuations, as well as on the influence of propeller geometry and efficiency (note: seems like we should follow up this last one). They segregate the design features for cavitation noise as: hull line design; appendage design; propeller design; and retro-fits. |

| | | |
|---|---|---|
| **Manfred Mehmel** (Potsdam Model Basin) | **2 Nov 09** | The Potsdam Model Basin works in ship hydrodynamics with special niches in designing propulsion systems and computational fluid dynamics. They have focused on reducing pressure pulses in the wake field to minimize hull vibration and they have some capabilities to measure very low frequency noise. They provide some useful background information on underwater acoustics related to propulsion systems (see below in detail). They also reiterate previous conclusions that the optimal design of propellers from a quieting perspective is slow moving, large-diameter, non-cavitating propeller with many blades in a uniform flow. They note that for quiet vessels, other sources on the ship and the impact of waves on the hull can contribute to radiated noise. |
| **Jan Hallander**<br><br>(SSPA Sweden AB) | **9 Nov 09** | SSPA is one of the major model basins in the world for testing and optimizing commercial ships; they also have experience in testing naval vessels and underwater vehicles where radiated noise is a very important issue. [This is verbatim because I thought interesting in light of something Kathy said recently: "In addition to model testing we assist our customers with advisory, calculations and simulations at all stages of the design process. In some projects we are assisting the customer in developing a new concept before contracting a shipyard while in other projects we are assigned by the customer just for validation and verification."]. Optimum propeller design is usually a trade-off between efficiency and cavitation performance; high efficiency and thus low fuel consumption has usually the highest priority among commercial ship-owners. Where radiated noise is an important criterion, cavitation can be avoided by lowering the propeller loading, but this comes at the cost of lower efficiency and thus higher fuel consumption. Optimizing hull design can both increase the hull efficiency and achieve a smoother wake field (inflow) which gives the propeller better acoustic performance, although load carrying capacity, port and fairway restrictions can be limiting. For a standard commercial ship, there are drivers to reduce underwater radiated noise, but they do care about hull vibrations for interior noise and/or structural fatigue. There are standard measurements for monitoring hull pressure pulses. In terms of underwater low frequency radiated noise, the prediction of radiated cavitation noise is more complicated than just applying scaling laws to model scale measurements from test basins for several reasons including where the measurement is made (close to the source) and the fact that some of the noise is radiated directly into the water and some is radiated secondarily through the hull. The relationship between scaled models and full scale far-field noise fields will differ for different ship types. They conclude that the acoustic consequences of designing ships with better fuel economy will probably be marginal since there are requirements on pressure pulses and vibration. |

___________