REVIEW OF LEGISLATION ON NOISE AND VIBRATION REGULATIONS IN MERCHANT SHIPS

(DOI No: 10.3940/rina.ijme.2015.a3.315)

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SUMMARY

This paper aims to describe the evolution of noise regulations for merchant ships over the last four decades, analysing the most important aspects with respect to crew, passengers and exposed populations in cities, in line with the requirements of the European Union to reduce the environmental impact of transport. The paper also analyses the changes in regulations aimed at not only regulating noise and vibration inside the ship, but also noise emitted to the port and underwater radiated noise. We shall also include Classification Societies, given the importance of their standards in ensuring increasing levels of comfort on board ship.

1. INTRODUCTION

Previous strict specifications regarding the maximum levels of noise and vibration on board ship reflected the need for extremely careful planning from the early stages of ship design. This process involves detailed analysis of the different elements of the "acoustic transmission paths", identifying and characterizing the sources of noise on board, its receptors –situation and required limits– and the transmission paths linking the source with the receptors.

Two factors exist in the technological evolution of vessels that increase the problem of noise and vibration on board:

a) The reduction in scantlings in the structures that form the vessel leading to increased flexibility and a reduction in the typical vibration frequencies of individual elements as well as of assemblies of such elements.
b) Increased service speed and size respectively aimed at reducing transit time between ports and increasing capacity, which require the use of higher power propulsion engines and lead to increased rigidity in the shaft line.

To study noise and vibration on board ships, it is necessary to consider the sources of excitation as well as the structures that may be exposed to this excitation. Once the sources and affected structures are known, resonance phenomena may be studied to avoid excessive dynamic amplification. It is therefore advisable to maintain the different frequencies far from any foreseeable excitation frequencies.

Irrespective of the phenomenon of direct resonance between the sources of excitation and the structural elements of the assembly of the hull girder, some local structural assemblies may act as localized resonators capable of creating additional dynamic amplification of the stresses produced by the sources of excitation.

To further complicate the problem, the phenomenon of beats may cause resonance in structures whose actual frequencies are different from each of the excitation frequencies.

2. SOURCES OF NOISE ON SHIPS

The main vibration excitation sources (noise emission sources) in ships are: the propellers, the primary machinery, heating, ventilation and air conditioning (HVAC) systems, and exhaust gas systems.

There are also secondary sources of noise, such as: auxiliary machinery, hydraulic systems, different types of pumps, and the effects of the sea, wind, etc.

2.1 THE PROPELLERS

The propeller produces two types of excitation:

- Alternative thrust: giving rise to longitudinal vibrations in the shaft and machinery, which depends on the blade step-frequency - propeller revolutions multiplied by the number of blades (rpm.N) -, and their harmonics.
- Vertical pressure forces in propeller aperture: causing vibration in the hull and superstructure induced by propeller cavitation.

Given the above, the propellers are often the main cause of the high noise levels that arise astern and most of the low frequency noise in remote spaces, which spread to distant spaces via induced vibrations through the shaft line and surrounding surfaces of the outer shell. Interaction between the propeller and the hull is normally responsible for low frequency noise between 1 Hz and 1 kHz

2.2 LOW SPEED MAIN DIESEL ENGINES

Although there are vessels with diesel-electric engine propulsion systems and, to a lesser extent, steam turbines, most ships employ reciprocating internal combustion engines (slow speed diesel engines) as their propulsion system. There are two different types of forces that may be associated with reciprocating internal combustion engines, namely: Pressure forces due to combustion processes, and inertial forces. Both contribute to the vibration occurring in the engine structure. However, their destructive potential lies in their resonance with the lowest vibration modes of the hull reinforcements.

Table 1. Average noise levels in dB(A) obtained experimentally [1].

Type of engine	Slow	Medium Group 1	Medium Group 2	Medium Group 3	Fast
RPM	110-200	200-400	400-600	600-1.000	1.000-1.800
Maximum	95-110	95-110	98-115	99-117	105-122
Average	89-100	90-107	95-110	97-112	97-113
Control room	69-80	70-80	74-80	80-86	87-88

Table 1 shows that noise emission increases with engine speed and that the values are above 95 dB(A). It may therefore be stated that the permissible continuous exposure limit is exceeded in all motor vessels in the engine room and that there is a need for a suitable control room.

The different types of noise emission generated by a diesel engine are the following: exhaust gas noise (due to gas pulsations), airborne noise (noise generated in the engine room) and structural noise (due to vibration in the engine bedplate) (figure 1).

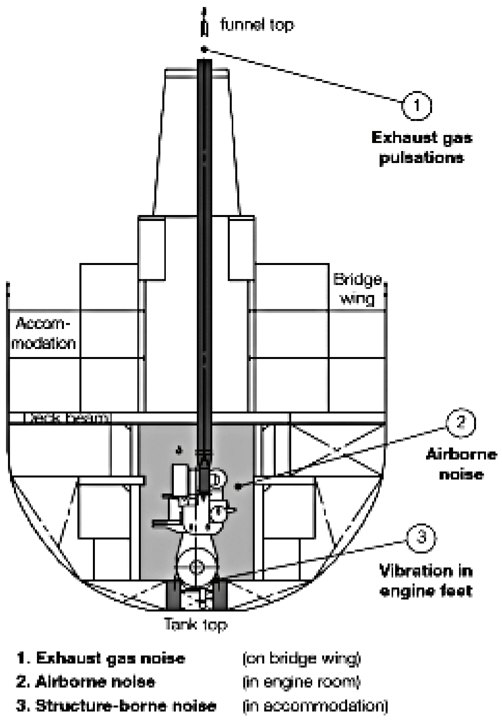

Figure 1. Types of noise emission generated by slow diesel engines on ships [2]

2.3 VENTILATION AND AIR CONDITION

Forced ventilation and air conditioning systems are often the third major source of noise. This noise originates from:

- The fan itself and its motor.
- Air ducts and ventilation rates.
- Air entering the system due to suctioning.
- Air exiting the system through diffusers.

The noise in the ducts is due to two main factors: air speed and abrupt changes of direction in the elbows and intersections.

3. NOISE STANDARDS

There is a need to differentiate between what is called health and safety on board and safety of life at sea.

Occupational health and safety on board falls within the scope of the prevention of occupational hazards. The legal scope of this occupational legislation is mainly the competence of national and EU authorities.

Regulations on Safety of Life at Sea are international in scope, while still forming part of Occupational Health and Safety.

3.1 INTERNATIONAL MARITIME ORGANIZATION (IMO)

To achieve its objectives, the IMO has adopted more than 40 Conventions and Protocols, which are binding legal instruments and, once put into force, their provisions must be implemented by all States that have signed them.

Once they have entered into force, the implementation of IMO conventions depends on the Governments of the States Parties.

The IMO also adopts many non-treaty instruments such as codes and recommendations. These codes and recommendations are not mandatory instruments; although Member States are expected to implement the provisions laid down in them.

There are currently over 800 codes, covering all areas of navigation. These include the Code on noise levels on board ships A.468 (XII)(81) [3], adopted by the IMO in 1981.

3.2 NEW IMO REGULATION MSC 337. (91).

Seeing as the previous regulation dated from 1981, in October 2007 the Maritime Safety Committee (MSC) decided to revise the code (MSC83). The revision was completed in November 2012 and its amendment entered into effect in July 2014. The revised noise limits distinguish between two ship sizes:

- 1,600 up to 10,000 GT
- 10,000 GT and above

The purpose of the Code is to limit noise levels and reduce worker exposure. The Code is not intended to be applied to passenger cabins or other passenger spaces, except insofar as such spaces are work areas, in which case they remain within the scope of the Code.

The set noise level limits are designed to ensure that seafarers will not be exposed to an L_{ex} [25] exceeding 80 dB(A), i.e. within each day or a 24-hour period the equivalent continuous noise exposure would not exceed 80 dB(A). In spaces with sound pressure levels exceeding 85 dB(A), suitable hearing protection should be used, or time limits for exposure should be applied to ensure that an equivalent level of protection is maintained [4].

Table 2. Noise level limits in bridge and machinery spaces [3] and [4]

Designation of rooms and spaces	**New Code**		**Old Code**
	1,600 up to 10,000 GT	**≥10,000 GT**	
Work spaces (in dB(A))			
Machinery spaces permanently manned			90
Machinery spaces not permanently manned			110
Machinery spaces	110	110	
Machinery control rooms	75	75	75
Workshops	85	85	85
Non-specified work spaces	85	85	90
Navigation spaces (in dB(A))			
Radio rooms	60	60	60
Look-out posts	70	70	70
Accommodation spaces (in dB(A))			
Cabins and hospitals	60	55	60
Mess rooms	65	60	65
Recreation rooms	65	60	65
Open recreation areas	75	75	75
Offices	65	60	65

Table 2 shows that the recommended noise levels are maintained with two exceptions: non-specified work spaces, in which the maximum noise levels are reduced by 5 dB, and in machinery spaces (in which the distinction between permanently manned or not permanently manned spaces has been removed), representing an increase of 20 dB.

The limits have not been modified in navigation spaces, ranging from 60 dB in radio rooms and 70 dB in navigating bridge wings. Hence, the auditory stress suffered by bridge and radio staff is much lower than that suffered by engine room staff. The remaining spaces continue to have the previous noise level limit.

There is an improvement in the limit in the accommodation spaces of vessels of 10,000 GT and above, being reduced by 5 dB compared to the levels of the previous code, except in recreation rooms, where the level is maintained at 75 dB.

The new code will, in general, be mandatory, though some parts will not: for instance, those parts referring to existing vessels of 1,600 GT and above, and new ships of below 1,600 GT, operating conditions in port, noise exposure limits, insulation materials and the selection and use of hearing protectors, in addition to all the appendices except for the first one.

The new code establishes that a noise survey report is to be made for each ship and that this report is always to be carried on board.

3.3 NATIONAL REGULATIONS

The one currently in force is R.D. 286/06 [6]. Although initially excluded on-board staff, the Transitional Provision established that it is to be applied to these workers from November 2011. Although this legislation is better than nothing, it only makes reference to daily noise exposure limits and the values are quite consistent with IMO regulations.

3.4 CLASSIFICATION SOCIETIES' (CS) REGULATIONS ON NOISE

In addition to international standards and national regulations, CS have included in their Regulations a notation aimed at assessing comfort with respect to noise and vibration on board.

The following Noise Standards are frequently used by CS:

- IMO Res. MSC 337(91) - "Adoption of the code on noise levels on board ships.
- ISO 2923:1996, "Acoustics - Measurements of noise on board vessels.
- ISO 140, in particular Part 4 (Field measurements of airborne sound insulation between rooms) and Part 7 (Field measurements of impact sound insulation of floors).
- ISO 717 (Rating of sound insulation in buildings and of building elements), in particular Parts 1 (Airborne sound insulation) and 2 (Impact sound insulation).

Although some of these Standards have recently been revised, the CS are still using the previous ones.

Of the ten companies that are members of IACS (International Association of Classification Societies), the most important worldwide are: American Bureau of Shipping (ABS), Bureau Veritas (BV), Det Norske Veritas (DNV), Germanischer Lloyd (GL), Lloyd's Register (LR) and Registro Italiano Navale (RINA).

The required levels of noise are very similar in all CS; small differences existing between the requirements for passenger cabins (first class or standard) and outdoor facilities (Table 3).

Table 3. Summary of the "Comfort Class" of different CS.

Type of space	Noise limit dB(A) Minimum	Maximum
First class passenger cabins	44	56
Standard passenger cabins	49	60
Crew cabins	50	60
Wheelhouse	55	65
Engine room	108	110
Unmanned machinery spaces	85	90
Engine control room	67	80
Workshops	80	85

The location of the points of measurements and tolerances are the criteria that mostly differ from one Classification Society to another. The majority of Societies employ tolerances, although they differ with respect to their criteria. Some Societies allow exceeding a percentage of maximum levels (BV, DNV, RINA), for others, excessive levels lead to new measurements (LR) while no tolerance is supported in other cases (ABS, GL).

While Classification Society requirements regarding vibration vary considerably (although they are lower than the ISO standard) [8], there is substantial consensus on noise requirements.

3.5 EUROPEAN DIRECTIVES ON NOISE

Through its "Green Policy", the European Union has imposed increasingly stringent requirements to reduce the environmental impact of all types of transportation. These requirements are presented in three areas:

- Noise and vibration on board ships
- Noise radiated from ships in ports
- Underwater radiated noise

We shall now briefly enumerate the regulations regarding the last two groups, as that relating to the first group has been analysed in the preceding sections.

3.5.(a) Specific regulations for the control of noise radiated from ships to the port and inhabited areas in inland waterways

2001 - EN ISO 2922:2000 [9]. This standard specifies the conditions for the measurement of airborne noise emitted by vessels of all types on inland waterways and harbours, except for powered recreational craft, as these are regulated by ISO 14509. It is applicable to small offshore vessels, harbour craft, dredgers and all those watercraft, including those that are berthed, used as or with the capacity to be used as a means of water transport.

2002 - Directive 2002/49/EC [10]. This Directive has the following aims:

- To establish a common approach intended to avoid, prevent or reduce on a prioritised basis the harmful effects, including annoyance, due to exposure to environmental noise.
- To provide a basis for developing EU measures to reduce noise emitted by major sources, in particular rail and road vehicles and infrastructure, aircraft, outdoor and industrial equipment and mobile machinery.

2006 - Directive 2006/87/EC. The noise generated by a vessel under way shall not exceed 75 dB(A) at a lateral distance of 25 m from the ship’s side and the noise generated by a stationary vessel shall not exceed 65 dB(A) at a lateral distance of 25 m from the ship’s side, apart from transhipment operations.

2007 - EN ISO 14509-2:2007. This specifies procedures for assessing the maximum noise emitted by powered mono-hull recreational craft of up to 24 metres in length.

2009 - EN ISO 14509-1:2009. This standard evaluates emitted noise using calculation and measurement procedures.

3.5.(b) Regulations and standards pertaining to ship underwater radiated noise

Although the main source of underwater radiated noise is obviously the propeller, as well as the propulsion machinery due to inducing structural vibration, there are also other features that influence the emission pattern and intensity of the radiated noise are: the directivity of the sound, the dimensions of the vessel and its speed (the faster the speed, the higher the emissions), load conditions (higher emission levels when the ship is in ballast condition), type of propeller (controllable pitch propellers are the most problematic) and vessel maintenance.

The receptors of this noise are marine wildlife in general, although marine mammals are affected the most, as they rely on sound to communicate, coordinate their movements, navigate, explore the environment, find food and avoid predators. The absence of environmental requirements regarding ship underwater radiated noise has been widespread in almost all contractual specifications until now, with the exception of the most modern oceanographic and fisheries research ships. However, the emergence of international, national and regional associations for the protection of marine mammals has led to the drawing up of a series of regulations that address underwater radiated noise and its

Table 4. **-** This table summarizes the evolution of noise regulations on ships.

	Noise on board (inside the ship)	**Radiated noise in ports**	**Underwater radiated noise**
1974	SOLAS (Protection against noise)		International Union for Conservation of Nature RESWCC3-0638
1975	IMO A.343 (XII)		
1981	IMO A.468 (XII)		
1984			
1990s	Comfort Class Notations		
2000			
2001		ISO 2922:2000	
2002		Directive 2002/49/EC	
2003	Directive 2003/10/EC ILO Maritime Labour Convention		
2006	Directive 2006/87/EC ILO Convention No. 188 (Fisheries sector) ILO Recommendation WFS		ICES No. 209
2007	Review IMO A.468 (XII) (85 dB(A) – 80 dB(A))	ISO 14509-2:2007	Directive 2008/56/EC
2008			
2009		ISO 14509-1:2009	Silent Class
2010			
2012	MSC 337(91)		

potentially adverse effect on marine life. Noteworthy in this respect is the International Council for the Exploration of the Sea (ICES), whose Requirement 209 sets a limit to the level of lateral noise radiated underwater by the vessel at 1 m from the ship's side. By means of the ICES methodology, it has been found that the noise radiated by the ship's hull at 1 metre from the hull should not exceed 132 dB [11].

In this sense, Directive 2008/56/EC [12] comprises an international legal instrument which includes human-induced underwater noise in the definition of pollution. Also the Acoustical Society of America has published a Procedure for measuring underwater radiated noise [13].

In 2010, the DNV Classification Society issued the Silent Class Notation [14], setting different limits for each type of vessel. This notation includes procedures for measuring underwater radiated noise.

It can be seen that regulations are being drawn up to define the requirements for new construction ships which will include limits for different aspects of the total acoustic signature (Noise and Vibration Full Signature) of each vessel: noise and vibration on board, noise radiated to the port and underwater radiated noise.

Table 4 provides a summary of noise regulations in three areas. IT can be seen that regulations on noise on board ships have been developed further than those on radiated noise in ports and underwater radiated noise, as the awareness of noise pollution from means of transport reached a highpoint in the last decade.

3.6 EUROPEAN PROJECTS ON NOISE (Related to Directive 2002/49/EC)

Ecoports: Research projects focused on the development and implementation of tools to improve the environmental characteristics of ports. This project includes NoMEPorts

NoMEPorts: Its main objective is the reduction of noise related to health problems and annoyance caused to citizens living near industrial port areas using noise maps (with the help of specialized software for predicting noise) and a noise management system to be used specifically in industrial port areas.

The noise sources related to traffic in port areas are the roads, railway infrastructure and air traffic. Examples of sources of industrial noise in port areas are the port facilities, terminals, cargo handling and storage terminals, industrial sites, machinery and workshops, ships under construction, repair and maintenance, slipways and moored ships (engine noise).

This project has carried out an analysis of the characterization of the different sources of noise in a port which has shown that the contribution of ships to ambient noise is primarily <u>due to the operation of internal combustion engines</u>.

Harmonoise/Imagine: These projects have developed a methodology for modelling various types of noise sources. The Harmonoise project focuses its efforts on noise prediction methods for roads and railways, while the scope of the Imagine project extends to the sources of aircraft and industrial noise. It considers only industrial sources because the noise emitted by ships is included in this source category.

SIMPYC: The objectives of this project include finding solutions to certain problems arising in relations between the port and the city aimed at establishing a friendlier environment and a functional relationship model, while developing coordination between port activities and the city. These problems are basically: noise pollution, air pollution and environmental impact.

HADA: This project is a tool designed to establish a methodology to control noise levels in Spanish seaports (table 5). As in most ports, the main sources of noise are the movement of metallic parts, road haulage traffic and trains. Ships constitute a medium-low source of noise impact, with the exception of the noise emitted during loading and unloading operations.

Table 5. Summarized inventory of sources of noise around port areas.

Inventory of sources of noise around port areas	
Priority level	**List of activities and sources of noise**
High	Scrap iron (unloading of the ship at the dock and loading from the dock to the truck)
	Iron and steel products
	Containers
	Repairs
	Shipbuilding
	Heavy traffic
Medium	Railway noise
	Port warehouses (depending on the type of goods)
	General merchandise (non-ferrous metals, wood, paper, plaster …)
	Dockage of Ro-Ro vessels
Low	Liquid cargo without special facilities
	Solid cargo without special facilities
	Petroleum products due to their special facilities
	Fishing: sale, ice plant, refrigerators, etc.
	Passenger ships: ferries, cruise ships

SILENV project [15]: Among other objectives, this project aims to assess methodologies and criteria for the analysis of the noise ships emit to the outside. One of its goals is to model the propagation of airborne noise to the outside by various types of vessels.

In general, strategic noise maps are obtained by superimposing the calculated sound fields for each source (ships and other possible contributions). The ultimate goal is to assess the noise levels produced in receptors (population exposed to noise), i.e. the population living near the port.

AQUO Project: The aim of this project is to assess and reduce the underwater acoustic impact from maritime traffic using tools to detect, predict and reduce ship radiated noise.

4. ANALYSIS OF NOISE LEVELS IN DIFFERENT TYPES OF SHIPS

After nearly four decades of developing regulations regarding shipboard noise, it is our opinion that the hearing health of seafarers is still not adequately protected. Nonetheless, ships classified by companies belonging to IACS are in a better situation because of the higher technical requirements of this organization, which include not only limits to noise and vibration levels, but also sound insulation and impact sound limits. The additional requirements on noise emitted to the outside set by the European Union will favour the reduction in noise on board, and *vice versa.*

A review of noise levels on board ships measured by different agencies and researchers over the years reveals the following values:

a) Nilsson [16], measured existing levels in 282 cabins on 15 vessels chosen at random, finding the distribution shown in the following figure 2:

As can be seen, the recommended level of 60 dB(A) is exceeded in two thirds of the cabins.

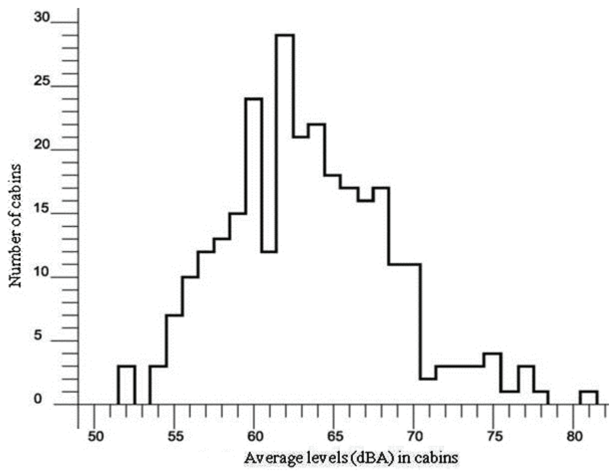

Figure 2. Histogram distribution of noise in 282 cabins on 15 different ships.

b) Szuwarzynski *et al.* [17] studied the distribution of noise in 1,360 cabins on 45 merchant ships, finding that the limit of 60 dB(A) is exceeded in only thirty percent of these, as shown in the following figure 3.

c) Experimental levels in bulk carriers, [18] The table 6, was obtained by measuring noise levels in fourteen ships of the same size and type (bulk carriers), built in the same shipyard, with the same propulsion engine, machinery and accommodation aft, in the same ballast condition during speed trials and with the engine operating at maximum rpm. Average values are presented in Table 6.

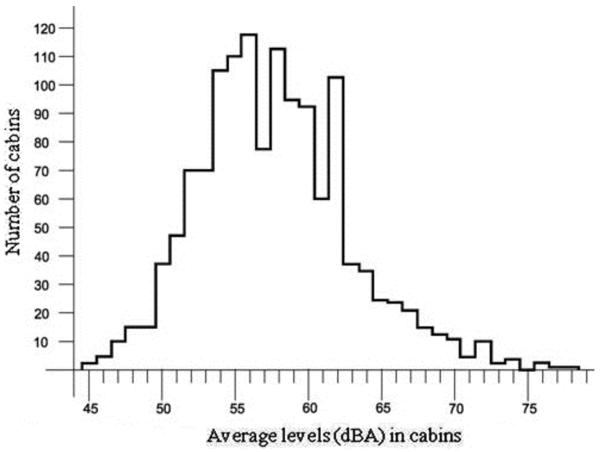

Figure 3. Histogram distribution of noise in 1,360 cabins on 45 different ships.

Table 6. Average noise levels in dB(A) of a group of 14 bulk carriers.

	NF	dB(A)	SIL
Workshop	94	98	91
Galley (with extractor fan)	82	84	77
Galley (without extractor fan)	69	74	68
Cabin (main deck)	65	67	55
Cabin (lower deck)	57	61	50
Cabin (officers' deck)	56	61	47
Cabin (bridge deck)	54	59	49
Control Room	75	79	71
Wheelhouse	-	68	-
Engine (top)	98	103	96

Engine Room.- The average noise level in the Engine Room was 104 dB(A), so it is essential to have an Engine Control Room. The average value in these was 79 dB(A), which exceeds the recommended level of 75 dB(A). Outside the control room, average values of 103 dB(A) were obtained at the top of the engine, so it is not possible to hold a conversation here without shouting. The recommended level in the Engine Room workshop was 85 dB(A), while the measured value was 98 dB(A) and hence too high. Understanding what is said here is hence very difficult.

Wheelhouse.- The average level was 68 dB(A), while the recommended limit is 65 dB(A).

It can be seen that the limits are generally exceeded in almost all spaces on board.

d) Experimental levels of noise on tankers, Buiten [19] obtained the results discussed below from an experimental study of existing noise and vibration on eleven tankers ranging in size from 18,000 to 200,000 GRT.

The results for two representative types of vessels are summarized below: one of 200,000 GRT sailing at full load, and another of 70,000 GRT in ballast. On the 200,000 GRT vessel, a large difference in the noise level was registered between the Engine Room (105 dB) and Accommodation (68 dB), this difference increasing with increasing frequency (greater difference at higher frequencies).

A significant low frequency component existed in the crew cabins, dropping to 23 dB in the 31.5 to 250 Hz frequency range. A peak appears at 500 Hz which raises the noise figure (NF) to 67, practically coinciding with the sound pressure level of 68 dB(A).

Third octave band frequency analysis of the noise and vibration on board reveals dominant frequencies. A peak appears at 5 Hz attributable to the propeller, which was rotating at 5.4 Hz at the time of measurement. At frequencies between 10 and 63 Hz, a band of relatively constant noise was observed that was attributed to structural transmission of the engine noise which is partly radiated through the air to the cabin.

As for the 70,000 GRT vessel, the characteristic peak of propeller noise is clearly observed at a frequency of around 8 Hz, the propeller rotating at 7.9 Hz at the time of measurement.

The bridge crew was subjected to an equivalent continuous sound level of 66 dB(A), and to 71dB (A) in the mess and 68 dB(A) in their cabins. Similar values were found for the rest of the deck crew.

e) Summary of noise levels for various types and sizes of vessels from the DNV CS [20], of average noise levels in dB(A) for different types and sizes of vessels (table 7).

Table 7 shows that the higher the deck is with respect to the engine room, the lower the level of noise. Nevertheless, in almost no case does it exceed 65 dB(A) (except in vessels of less than 1000 DWT), when the cabin is located above the superstructure. This value is exceeded, however, when the cabin is located below the superstructure.

The values recommended by the IMO are 60 dB(A) for smaller vessels and 55 dB(A) for larger vessels. These limits are met in cargo ships from deck B (second deck starting from the main deck). The vessels that most fail to meet the recommendation are small container ships. Clearly, the sound insulation of cabins located on the main deck, and those below it needs to be improved, or accommodation should be located exclusively from the lower deck with respect to the main one.

Table 7. Noise levels on different types of vessels. Source: DNV

Type Ship		Ship's Group	Engine Room	Control Room	Cabins: Under Superstructure 2	Cabins: Under Superstructure 1	Cabins: Over Superstructure A	Cabins: Over Superstructure B	Cabins: Over Superstructure C	Cabins: Over Superstructure D	Deck Bridge	Bridge Wings	Areas of outdoor recreation
Aft Superstructure	Tanker Carrier	A_1 /turbo	95-100	69	--	65	57	54	50	48	56	65	70
	Bulk Carrier	A_2>50000 TPM	96-108	72		66	60	57	54	51	59	69	70
	OBO	A_3>5-10000TPM	100-110	73		67	62	59	56	53	61	71	75
	LPG/LNG	A_4>1-5000 TPM	103-110	76		69	64	61	58	55	63	73	75
	General Cargo	A_5>50000 TPM	103-110	80		71	66	63	60	--	65	75	80
	Container Ship	A_6<1000 TPM	105-110	--		75	70	67	--		69	79	--
¾ Aft superstructure	Reefer Container Ship	B	100-110	75	--	67	60	57	55	53	60	70	75
Fore superstructure	Ro-Ro	C	105-110	78	--	60	55	52	49	47	57	65	70
	Container Ship												
	General Cargo												
	Offshore	D Traffic Manoeuvring	107-112	80	62	61	58	55	--	--	63	79	--
	Tugs				81	75	69	63			66	79	
	Passenger ships		105-110	75	75/45	71/43	66/48	62/43	56/42	54/39	55	65	70
	Cruise Ships												
	Ferries												

As for the noise levels of the wheelhouse, the limit recommended by the IMO of 65 dB(A) is once again not met by tugs when manoeuvring or in small container ships. In general, there seems to be no problem in these spaces.

Table 8. Summary with maximum noise levels in different spaces, in all constructions.

	Ro - Pax Vessels (<200 m)				
	78/ 79	**80**	**81**	**86**	**Juan J. Sister**
Engine Room	105	105	105	110	109
Engine Control Room	85	70	68	74	71
Wheelhouse	64	65	61	61	54
Cabins	61	55	53	70	59
Recreation areas	--	61	60	71	79
Workspaces	86	85	84	90	92

The value recommended by the IMO for the engine control room is 75 dB(A), which is not met in low tonnage ships, such as tugs, general cargo vessels of below 5,000 dwt or Ro-Ro vessels. This may be because there is no control room separated from the machinery spaces on the majority of these small tonnage vessels.

Finally, the noise levels in the engine room exceed 100 dB(A) in almost all vessels. The only vessels found within a range whose lower limit is below 100 dB (A) are those powered by turbines (currently a very small number of vessels with respect to the world fleet) and bulk carriers of 50,000 dwt and above.

f) Summary of noise levels on Ro-Pax vessels [21] (data from LAV, Cadiz). Measurements made by the Acoustics Laboratory (Spanish acronym, LAV), University of Cádiz, were primarily used to prepare Table 8.

5. CONCLUSIONS

By requiring shipyards to make a predictive calculation of noise in the design phase of new construction ships in the areas of the vessel that must comply with noise levels stipulated in the fourth chapter of the Code, the new IMO Code involves a significant change in the traditional treatment of noise and vibration on board on the part of shipbuilders.

Furthermore, this Code requires the drawing up of a final noise report, which must be deemed satisfactory before delivery of the vessel to the ship-owner. In our opinion, noise levels on board should be checked on a periodic basis, and not just on completion of construction.

The new regulatory requirements being introduced by the European Union on noise radiated to the outside and underwater radiated noise will also make noise and vibration critical in the design of new ships. This will constitute a niche market for shipyards that take these requirements into account and will suppose a challenge for shipbuilding in Spain, which will need to adapt its processes so as to meet standards imposed at a global level to reduce noise pollution.

IMO requirements concerning the use and instruction to use hearing protection should be included among the operational procedures of the ISM Code for the Safe Operation of Ships, leading to increased awareness on the part of crews and effective control on the part of maritime agencies when performing audits.

We also highlight the differences that exist with respect to workers on land, especially during periods of rest.

From the data on noise levels in Section 4, it can be seen that:

- The level of noise in the different workspaces on merchant ships routinely exceeds recommended levels in the governing regulations. We believe this is why the Classification Societies permit tolerances of compliance.
- In general, the requirements of Classification Societies are more demanding (except with respect to Grade 3) than IMO requirements. Thus, if the average level measured on board is close to the IMO limit, the noise level may be considered "improvable", while if the average level is 5 dB or below this value, the noise level may be considered "acceptable". Obviously, values exceeding these limits are totally unacceptable and corrective measures must be taken.
- In general, the places on the vessel where these recommended levels are systematically exceeded are machinery spaces. This is compounded when considering that the IMO has set a level of 110 dB(A) on for all machinery spaces. This is seriously harmful for engine room staff. This amendment to the regulations for machinery spaces will require mandatory actions in new construction ships of 1,600 GT and above to avoid exceeding the level of 80 dB(A) of daily exposure to noise.
- There is an improvement in the limit in the accommodation spaces of vessels of 10,000 GT, although we understand that it should also apply to vessels of below 10,000 GT.
- These standards and recommendations do not pay due attention to vibration (closely related to noise) or to the frequency spectrum to determine whether there are tonal components, low frequency noise, impulse noise or reverberation, setting only the maximum overall equivalent continuous levels in dB(A) and, in some cases, the NR (Noise Rating) feature. In our opinion, therefore, other criteria, such as RC Mark II [22], used by ASHRAE [23] for interior spaces, should be employed so as to take into account the subjective degree of discomfort for people due to noise, in addition to its level. Neither do the standards take into account indicators on the intelligibility of communications, such as the SIL index [24].

In line with the results obtained in the SILENV project [15]), we may state that:

- Strict compliance with IMO (noise) and ISO (vibration) requirements on the ships making up the current fleet (regardless of the compliance of some vessels in particular) is not achievable in the short to medium term.
- Attempts to apply more stringent limits than current standards to the existing fleet will entail higher percentages of incompliance, given that the European merchant fleet does not generally comply with this new environmental regulatory framework. This will dictate corrective policies.

Possible strategies to improve the situation include:

- Specific policy actions to reduce the environmental impact of ships.
- A gradual renewal of the fleet is more feasible, given that the average age of the fleet means that modifications to improve the environmental impact of its vessels is not economically viable and the technical execution of such measures is likewise problematic.
- Any project promoted by the EU should reconcile three environmental issues: energy efficiency, gas emissions and noise emissions.

Thanks to the policies that are being developed within the European Union, the improvement in radiated noise in port and underwater radiated noise will also be accompanied by an improvement in the noise level inside the vessel, and *vice versa*.

The EU's regulatory framework for noise and vibration needs to be further developed to achieve lower levels of noise and vibration emitted by ships both at sea and in port, integrating ports into their cities, as pollutant source, for incorporating it into of strategic noise maps.

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