ACHIEVEMENT OF THE NEW UNDERWATER RADIATED NOISE REQUIREMENTS BY THE SPANISH SHIPBUILDING INDUSTRY. THE FRV *"RAMÓN MARGALEF".*

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1 INTRODUCTION.

The new EU's "Green Policy" and the new IMO regulation focused on reducing the environmental impact of all kind of vessels, origins a certain number of new directives that shall affect the Shipbuilding Industry. The authors' participation in the SILENV and in the BESST projects within the FP7 has permitted to notice that the underwater radiated noise by the ships became the most outstanding novelty and the stronger challenge that needed to be technically solved.
Following this new trend, the appearance of some class notations with "different limits" and containing assertions such as: "the propeller is the major noise source", and the lack of consensus that there is in the Biological community about the maximum noise levels that marine fauna can put up with, makes really difficult to define a clear technological strategy that should be followed. Until a consistent agreement is reached, the Shipbuilding industry and the Naval Engineers "will be fighting against a ghost".
In this "confusing scenario" this paper is a clear example of how the Shipbuilding industry is aware of this new topic and how it is moving ahead to reduce the impact of the new ships. The dynamic and acoustic design that was carried out by the authors of the FRV "*Ramón Margalef*" for the Oceanographic Spanish Institute together with the experimental results measured that show that the vessel fully complies with the most restrictive ICES and new IMO requirements, especially in the Machinery room, can be considered a clear proof of how the new requirements have been reached by the Spanish Shipbuilding Industry.

2 AN OVERVIEW OF THE UNDERWATER RADIATED NOISE (URN) SCENARIO AND THE NEW CHALLENGE FOR THE SHIPBUILDING INDUSTRY.

As it was previously mentioned and within the framework of the Green Policy of the EC and other Maritime Institutions such as IMO and ILO, all the targets defined are focused on combating and reducing the current "environmental impact" of all type of vessels that make up the current European Fleet. To fulfil this main target, special EC R&D projects have been promoted and launched to reduce the emissions as well as the Noise & Vibration (N&V) environmental impact of the vessels. BESST project, in charge of Cruisers and big Ro-Ro vessels, and SILENV project, oriented to all type of vessels, has been developed to attend the second priority worry: Reduction of the N&V impact of vessels.
A common conclusion brought out from both projects **[1]** is that the proper assessment of the environmental impact that all vessels cause, requires the complete knowledge of the so-called N&V-Full Signature (N&V-FS) of the vessel under study. This indicator is made up by the N&V on board, Noise Radiated to Harbour (NRH) and the Underwater Radiated Noise (URN). Taking into account that N&V on board requirements are well extended within the current fleet, it is therefore fairly easy to obtain N&V experimental data. On the other hand, in relation with the NRH (the novelty of the corresponding Directive 2006/87 EC) its coming in force postposition and, from the author's point of view, the confusion that there is amongst the Member States in its implementation, makes extremely difficult the presence of NRH requirements in the current contract specifications, of the new constructions. Consequently the availability of experimental NRH data is very low. Finally, based on the fact that the Underwater Radiated Noise became the most outstanding novelty in the Marine Sector, the unavailability of URN data, as a *"starting point"*, with few exceptions, is

almost general within the current fleet. Dedicated tasks, in the framework of the previously mentioned EC R&D projects: BESST and SILENV, have been developed to fill up this lack.
Considering that the availability of experimental URN data is an essential *"starting point"* to know *Where are we?* and so, *What should it be done in order to move ahead in the improvement of the current situation?*; it has been considered that it should be necessary to do an overview about the "URN State of Art".

2.1 State of Art 1: URN Data.

Related to the availability of URN experimental data it is well-known that for a long time and responding to strategic aspects, the Navy vessels have been highly concerned with their underwater noise levels. Target levels are usually specified for this type of ships. Many URN experimental data exists but, by obvious strategic reasons, they are confidential and not accessible. Concerning "civilian vessels" some interesting results of URN measurements can be found in the publications **[2, 3, 4, 5]**. These publications are very interesting because several URN signatures of various commercial vessels (mainly cruise ships), are presented. These URN levels come with detailed descriptions of the measurement conditions and of the ships' characteristics, which allows the analysis of the data.
This unwanted trend, related to the absence of URN experimental data within the current fleet, has been totally confirmed by the analysis carried out by the SILENV project **[6].** In the SILENV-N&V Database generated from a total of existing 151 vessels, only five (5) of them (3,1% of the total sample), have included specific URN requirements in their contract specifications. To enrich this poor scenario, dedicated on-site measurements activities were done to obtain the URN signature of ten (10) additional vessels (of different types), and therefore more available experimental data was collected.
Thus, as a summary, in this current scenario only the Navy Ships, because of their strategic requirements but with inaccessible information, and the FRV, because of their performance requirements (they must not disturb the fish species during the observation), have been the two families of vessels that have moved ahead in the abatement of their underwater footprint and therefore in their impact in the water.

2.2 State of Art 2: URN Measurement Procedures and Targeted URN Limits.

On 2009, ANSI-ASA launched its standard "Quantities and Procedures for Description and Measurements of Underwater Sound from Ships**" [7].** This URN procedure includes also the methodology for the reporting of the one-third octave band sound pressure levels. The resulting values are the sound pressure levels normalized at 1 m from both hull sides. The procedure selected has no inherent limitation with regard to the vessel's size. The aim of this procedure is to perform the measurement of the underwater sound pressure in the far field and after adjust the values obtained to the 1 m normalized distance from both hull sides. It responds to the same principle usually applied for checking military vessels. As far as underwater noise is concerned, it is important to remind that the measurement and post processing methods can significantly influence the obtained results.
In this standard, the noise level is assessed at the CPA (Close Point of Approach). The data window angle shall be +/- 30º from the CPA. DWL is the Data Window Length, along which the ship under test has to maintain stable operational conditions. The data acquisition and all the averaging made in the frequency-domain shall be linear with sampling and consistent with the so-called DWP-Data Window Period (obtained dividing the DWL by the vessel's test speed). After post-processing, the main result obtained is a noise pressure level spectrum. It is necessary to indicate the bandwidth. Usually the results are: the Noise pressure levels in third-octave in decibels referenced to 1µPa (dB re 1µPa at 1 m). Band levels are associated with the mid-frequency of the third-octave band. For many purposes, it is convenient to use the power spectral density per unit bandwidth (spectrum level).
An important parameter is the transmission loss (TL), used to calculate the radiated noise at 1m from the ship, and obtained from the level measured at the hydrophone location. The "real" transmission loss depends on many parameters (sound frequency, salinity, sea state, sea bottom, water depth, local sound velocity, etc) and to obtain a real and precise value would be very difficult.

That is the reason why, in measurement standards, simplified methods are used to assess the transmission loss (TL). Usually the formula TL = 20Log D_{CPA} (D_{CPA}: Distance of Closest Point of Approach) is applied for all the frequency bands (ANSI-ASA standard). Finally, ANSI-ASA defines no targeted limits.
Recently (in January 2010), DNV published a new standard for the measurement of the underwater noise emitted by ships **[8].** This standard "SILENT" specifies targeted limits and associated measurement procedures. The method used to define these limits is not known. The different targeted limits specified in this new standard are different, depending on the type of vessel considered. According to this Class Notation, the Society, based on an operational speed profile for typical hydro-acoustics operations submitted to it, will decide the "speed/s at which the vessel shall be tested". It is important to keep in mind that based on the practical expertise of the authors, this parameter becomes essential for the suitable dynamic-acoustic design of the silent vessels, and it should be defined and agreed at the beginning of the project. Likewise, in this Class Notation the TL is calculated according to the following formula: TL= 18.Log D_{CPA} – 5dB.
In the publications previously mentioned **[2, 3, 4, 5]** (URN measurements of cruise ships in Glacier Bay), the transmission loss is 20LogD_{CPA} above 200 Hz, and it must be adapted to local conditions for frequencies below 200 Hz (calculation details are not known at low frequencies). It is essential to keep in mind that the comparison of URN levels is only valid if the measurement procedure is similar in both vessels, especially for the transmission loss corrections.
Finally, since the 90s, the URN target limits defined by the ICES (International Council Exploitation of Seas) Nº209 Regulation **[9]** became a widespread standard used within the Fishing Research Vessels family, especially in the modern ones. This standard specifies limits for 1/3 octave spectrum levels, at a speed of 11 knots, as it can be seen in **Figure 1.**

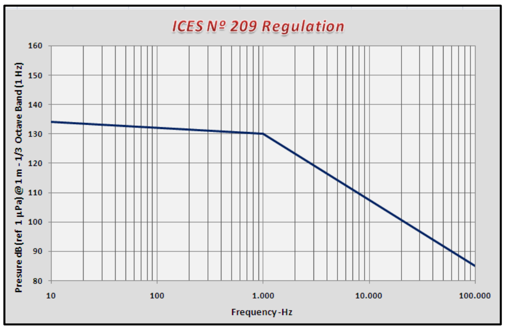


Figure 1.- ICES Nº 209 Regulation. URN target limits at 11 knots.-

2.3 State of Art 3: Operative experiences and data presentation. Debate about the "root causes" of the Underwater signature of vessels.

Within the current regulation framework, several operative experiences have been compiled. The first ones are related with the URN on-site measurements data processing and data presentation. In **Figure 2** the usual format for the presentation of the URN Spectra: Pressure (ref 1 µpa) @ 1m- 1/3 Octave Band (1 Hz) against Frequency (Hz) is reported.
In parallel an intense debate is occurring and its main purpose is to bring light on which are the main URN sources that affect the URN signatures of the vessels. In this concern, there are many experts that permit themselves to assert things such as: "the propeller is the principal root cause of the URN signature of the vessels" with no experimental support. This kind of assertions are made based on "old figures" and outdated information, where the propeller, of course, appeared as one of the main root causes of vibration on board. Based on the author´s point of view, with 36 years of experience as N&V consultant in the marine sector, with these "assertions" the Shipbuilding Industry is getting confused and cannot reach to understand what has to be done to move ahead on the improvement of the current situation.
To contribute to the enrichment of the debate, and in order to provide "practical tools or guides" to the Shipbuilding Industry for combating this new topic (additionally to the case study presented below), some observations should be considered.

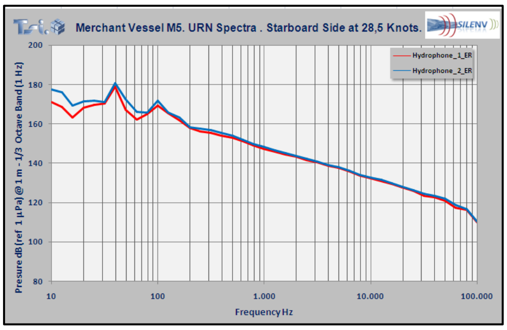


Figure 2.- Typical URN 1/3 Octave Band Spectra for Merchant Vessel at 28,5 knots**.-**

First, the disturbance introduced by the sea state and by the weather conditions in the hanging lines of the hydrophones are usually, but likely not always, affecting the signals of the hydrophones, particularly in the low frequency range 0-20 Hz. On the other hand, most of the few available underwater footprints of different types of vessels are reported in the format that was previously presented in **Figure 2**, 1/3 Octave Band Spectra (1 Hz) at different speeds and in the frequency range that goes from 10 Hz to 100 kHz, (eliminating, perhaps due to the reason explained before, the spectra in the frequency range 0-10 Hz). Taking into account that in most commercial vessels the tonal component induced by the propeller appears within this problematic frequency range 0-20 Hz, two (2) key questions arise: First*: How should the quantification of the real contribution of the main tonal component of the propeller be done?* Second: *Where can we find enough experimental data that supports the extended assertion that the propeller is the main underwater noise source?*

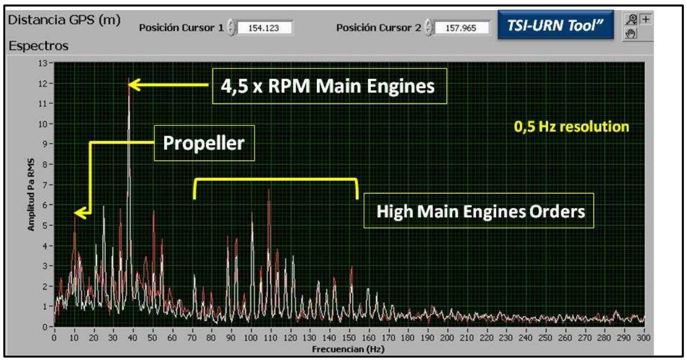


Figure 3.- Narrow band analysis for accurate identification of URN contributors**.-**

Finally and independently that for comparing with the targeted URN limits the information must be presented in 1/3 Octave Band Spectra, the proper an accurate identification of the underwater footprint of the vessel will require the use of dedicated acquisition and post-processing techniques that can make possible to obtain spectra with enough accuracy. This accuracy is needed if we want to identify if the excitation frequency came from mechanical parts of the machinery or from the propeller. In **Figure 3**, the narrow band analysis corresponding to the URN spectra presented in the **Figure 2** is reported.

These experimental results have also been confirmed with the assessment that was carried out and with the results that were obtained **(Figure 4)** for the SILENV project, for a total of fifteen different types of vessels: Merchant, Passenger, Fishing, Fishing Research Vessels, mainly**.**

As it can be seen, the Machinery and the Propeller, in this order, have been identified as the main contributors to the URN signature in a significant sample of vessels of the current European Fleet. This approximation is sound enough with the experiences that were documented at Glacier Bay, mainly related to Passenger vessels **[2, 3, 4, 5]**. Currently, and based on these experimental data, the message to the Shipbuilding Industry is clear: The abatement of the URN signature of the "new vessels" will require a preventive control of the sources and actions focused on reducing the vibration energy transmission from the main mechanical sources, as the main machinery, to the hull. The intensity of the excitation induced by the propeller must be controlled as well as its cavitation.

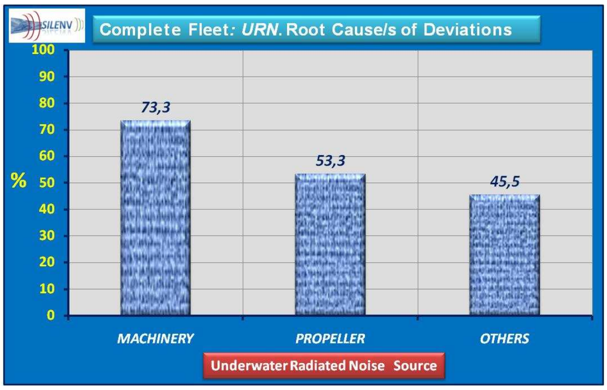


Figure 4.- Statistical Assessment. URN Root cause/s identification.-

2.4 State of Art: Summary.

First of all, it is unquestionable that the current debate amongst the scientific and technical marine communities as far as the impact of the underwater footprint of commercial vessels in the marine life is concerned, is in the limelight. On the other extreme we can find the current fleet for which, with very few exceptions (the FRV), there are no specific URN requirements included in their contract specifications. Consequently, the availability of URN data is limited and hence the impossibility to assess, with enough accuracy, the real impact of each family of vessels in the oceans and in the marine life. For moving ahead in the filling of this URN data lack, special mention should be done to the experimental database that was generated within the framework of the BESST and SILENV projects.
Other reasons for the current state (despite the intense debate in the EC and in all the Marine and Scientific Institutions that are concerned about the impact of vessels' underwater footprint in the marine life) are the novelty that this topic means for the civilian Shipbuilding Industry and, from the author's point of view, "the general confusion" that there is in relation with the harmonization of the measurement procedures and mainly about the limits. The ICES Nº209 limits appear, for some Scientists, "still quite permissive" but excessive for the shipbuilders: So, the conflict is still unresolved. As it will be detailed in the conclusions, the harmonization, the improvement of the measurement procedures and a "preliminary agreement" as far as the targeted limits are concerned between the scientific community and the Marine Sector is vital to define the technological strategy that should be followed for improving the current situation.
In this scenario, the real fact is that only the Navy Ships and the FRV have been the two families of vessels that have moved ahead in the abatement of their underwater footprint and therefore in their impact in the water. On the contrary, for the rest of the families of vessels of the fleet, the complete absence of specific URN requirements in their contract specifications makes impossible, as it has been proved with the SILENV project, the compliance with whichever the targeted URN limits are. From the author´s point of view those are the root causes of the current state of the European Fleet with regard to the impact of the underwater footprint of the vessels on the environment and, consequently, on the marine fauna. The premise "no one does nothing if they are not forced to" is therefore confirmed.
Based on the previous statement and on the extensive author´s expertise in building "silent ships", the Fishing Research Vessels Family, specially the most modern ones, becomes a point of reference and a clear example of the good practices and technological solutions that must be applied for minimising the impact of the vessels in the Oceans. They are a *"Technological reference"* because it will be possible to look at what type of dedicated solutions have been applied on them for reducing their URN signature. Of course, it must be kept in mind, that other factors such as cost/benefit ratios, fuel efficiency and technical viability should be considered and properly weighted. Besides, they will also be a *"strategic reference"*, because it will be possible to discover why the FRV family, contrarily to the other ones, are fighting and moving ahead in the abatement of

their underwater footprints. Of course, it will enable to increase the level of sensitization of the rest of the fleet with regard to this new topic.

3 CASE STUDY: FRV *"RAMÓN MARGALEF"*.

3.1. Introduction.

At the end of August 2011 the Fishing Research Vessel (FRV) "Ramón Margalef" was delivered to the IEO- Spanish Oceanographic Institute. As a result of the sea trial tests, the following main aspects could be highlighted: Maximum vibration level on board: ***0,7 mm/s-rms***; Noise on board at Cabins: between ***37 dB(A)*** *and* ***53 dB(A);*** and ***87 dB(A)*** at the Engine Room; Noise levels radiated to Harbour (NRH) in compliance with Directive 2006/87 EC (**lower than 65 dB(A)** at 25 m of both hull sides); and Noise Radiated to the Water (URN) in compliance with the ICES Nº 209 Regulation. These experimental results, respecting the most strict N&V comfort and environmental requirements, made the *"Ramón Margalef"* one of the *"most silent"* vessels of all the European Fleet and perhaps of the civilian fleet on the world. Thus this vessel become a clear milestone and indicator that the European Shipbuilding Industry and so, the Spanish one too, is capable of attending the current needs focused on abating the N&V environmental impact of vessels.
These results are not a question of luck, but they are based on solid pillars: The first one is the high level of sensitization shown by the Owner (IEO), who defined a technical specification that included specific requirements to guarantee: comfort and good working conditions of the Crew and Scientists, the reduction of the environmental impact of the vessel and, of course, the high efficiency of the scientific echo-sounders that are on board. Indeed, SIMRAD/KONSBERG**,** in another FRV in which the same methodology described below has been applied by the authors, has confirmed that the "low background noise of the vessel" has enhanced the efficiency of the electronic equipment more than 40%.
On the other hand, the excellent experimental results obtained enable us to validate and consolidate the Methodology *"Noise & Vibration Integrated Management"* that the authors have been applying for over thirty six years.
The aim of this paper is to present a brief description of the *"N&V Integrated Management"* methodology applied in the "Ramón Margalef". It is widely detailed in other author´s publications **[10, to 14]**. A summary of the experimental results obtained during the sea trial tests are also presented.

3.2. Description and Main Particulars of the vessel.

Because of its size and capacity, the FRV "*Ramón Margalef*" is classified as a regional fishing research vessel. She has autonomy for 12 days and can provide accommodation for 11 researchers and technician staff, in addition to a crew of 12 members. The *"Ramón Margalef"* has diesel-electric propulsion made up of three gen-sets driven by GUASCOR F480TA-SG diesel engines with an output of 868 kW at 1.500 rpm, elastically mounted according to the Criteria defined by the consultant (the authors). This plant produces all the power required to drive the two INGETEAM-INDAR KN-800-5-b-"c" DC Electric Motors, as well as all the electric power for the ship´s on board services and machinery. The vessels have two shafts driven each a single fixed pitch propeller. The Main Particulars and an overview of the vessel are reported in **Figure 5.**

Length Overall	46,70 m
Maximum Breadth	10,5 m
Design Draft	4,00 m
Depth to Deck Nº 3	7,10 m
Gross Tonnage	988 t
Dead Weight	230 T
Main Propulsion	2x 900 kW
Maximum Speed	13 knots
Classification	BUREAU VERITAS

Figure 5.- Vessel's overview and Main Particulars**.-**

3.3. The Methodology applied: Basic Principles.

Vessels are elastic systems under periodic forces that come from different sources. Consequently they are vibration sensitive. The vibration levels obtained in the system (the vessel) depends, mainly, on three parameters: 1) The Intensity or magnitude of the excitation forces. 2) How stiff is the structure. 3) The dynamic Amplification at different frequencies due to resonance phenomena: local and global. As a consequence, the *possible actions* that could be implemented if we want to keep *vibration levels* under certain limits are the following: A) Minimise the excitation forces of the system. B) Avoid flexible structures from a dynamic point of view. C) Avoid resonance phenomena (coincidence of structural frequencies and excitation frequencies).

Similarly, and from an acoustic point of view, the vessel has built-in Sonorous Sources: Main engine and Auxiliary ones, Propellers, Hydraulic Systems, HVAC, etc, that are airborne and structure borne noise generators. The noise is transmitted or spread through all the structure of the vessel (Path) and reaches all the different locals and spaces (Receptors) as well it is radiated to the water. In the same way, the *possible actions* that could be implemented in order to maintain the *noise levels* under the predefined limits are the following: 1) Minimise the sound power and vibration power at the noise sources. 2) Reduce or diminish their transmission to the paths. 3) Isolate the receivers.

From an elastic-acoustic point of view, the hull becomes a wave radiator to the water due to the acceleration induced on it by the action of the main mechanical excitation sources and to the propeller. In this case, preventive actions and sources control shall be applied focused on reducing the vibrational energy transmitted to the hull by the main machinery and by the propeller. So, dedicated FAT- Factory Acceptance Tests (for the main machinery) should be done, pressure pulses induced by the propeller and cavitation tests should be carried out for avoiding this phenomenon.

As a summary it could be stated and assumed by all the parties involved: designer, shipyard, main suppliers, insulation suppliers, etc; that, taking into account the strict N&V requirement defined in the contract specifications, the design principle that the *"Dynamic-Acoustic Design of the vessel"* shall be mandatory at all stages of the project. The role of the Consultant is to verify and guarantee that all the parties do their part.

3.4. The Methodology applied: Practical Application.

For the practical application of the previous "Basic Principles" in a "*first module",* inside the *"Noise and Vibration Integrated Management"(N&VCM)* and as a control mechanism, there have been incorporated *"dynamic and acoustic specific requirements"* in the purchase specifications of the different supplies as well as FAT Procedures, to control and verify their compliance before installing the most critical supplies on board. This *"first activity level"* has focused on the fact that the shipyard can develop a "control" of the main N&V and URN sources that are usually under the scope of the suppliers. The intention with this "control mechanism" is to achieve and guarantee the so-called "contractual sensitivity" of the suppliers towards the dynamic and acoustic objectives of the project. If this easy task is not performed, the shipyard finds out that, in many occasions, the solutions or countermeasures that should be implemented are more expensive. The wide expertise of the suppliers, involved in similar projects, has permitted, for the case of the "*Ramón Margalef*", an easy and efficient control.

The Shipyard assumed, from the beginning of the project, the fact that the "Dynamic and Acoustic Vessel Design" is mandatory. Thus, once the N&V main sources were under his control, a "second module or block of activities", that considered all the aspects that are competence of the shipyard, as it is the supplying of a vessel structure with an appropriate dynamic-acoustic design: with no resonances and with enough acoustic isolation to guarantee the compliance with the N&V contract requirements. Focused on achieving these N&V targets, a whole dedicated package of Simulation Tools and Dynamic Tests, such as N&V Prediction Calculations (**Figure 6**) and Radiated Noise: Outdoor and Underwater, Prediction Calculations, were put in play for the achievement of the optimal design.

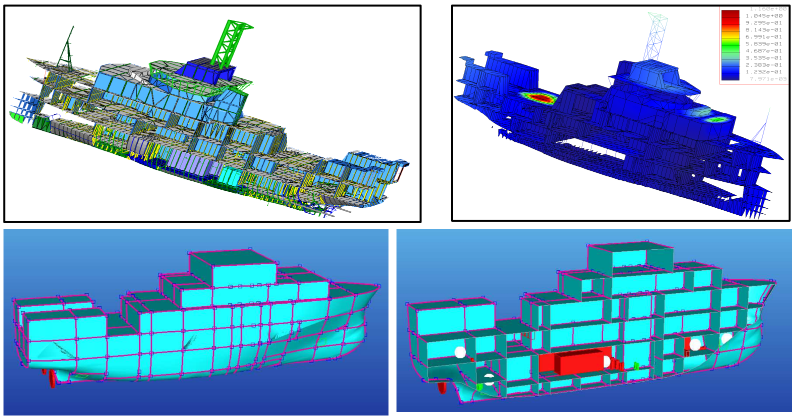


Figure 6.- <u>Simulation Tools applied for the Dynamic-Acoustic Design of the "*Ramón Margalef*".</u>-

To verify the fulfilment with the "Design Criteria" defined by the Consultant, related to the intensity of the excitations induced by the main machinery and by the propeller, as well as the theoretical results provided by the Simulation Tools applied, a whole package of model tests and on-site dynamic tests: FAT-Factory Acceptance Tests- and Inertance Tests, **Figure 7**, have been applied at different stages of the project.

Figure 7.- <u>FAT, Inertance and Model Tests, developed for the Design of the "*Ramón Margalef*"</u>.-

After all this entire analytical-experimental process, the vessel is ready to pass the most important test: the Sea Trial Tests.

3.5. The Sea Trial Tests: Results.

All the sea trial measurements were done at Vigo Bay (Spain) according to the Protocols that were previously approved by the Owner, the Shipyard and the BUREAU VERITAS. Some of the results are summarised in the below figures.

<u>Noise on board</u>.

For the Accommodation / Laboratories-Public, and Engine Room/Work spaces, the noise results obtained have been reported in the bar diagrams that can be seen in **Figure 8.**

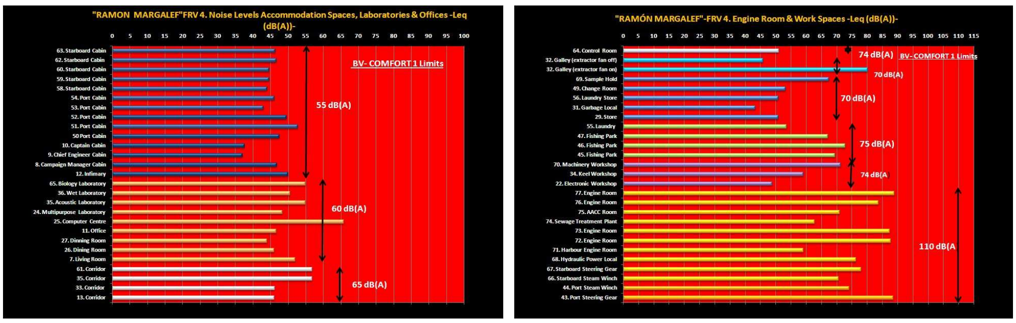


Figure 8.- "<u>Ramon Margalef" Noise on board: Accommodation and Engine Room spaces</u>.-

The numerical results reveal that: For Accommodation and Laboratory/Public spaces the Noise on board the average values are ***-9,6 dB(A)*** and ***-10,1 dB(A)***, respectively, ***LOWER*** than the corresponding BV-COMF VIB 1 limits (55, 60 and 65 dB(A), respectively). A special mention must be done for the Noise levels achieved in the Engine Room and in the Machinery spaces with an average value of ***-32,6 dB(A) LOWER*** than the BV´s limit (110 dB(A)) and than the new IMO amendment limits, in progress.

<u>Vibration on board</u>.

For the Accommodation / Laboratories-Public, and Engine Room/Work spaces, the vibration results obtained have been reported in the bar diagrams that can be seen in **Figure 9.**

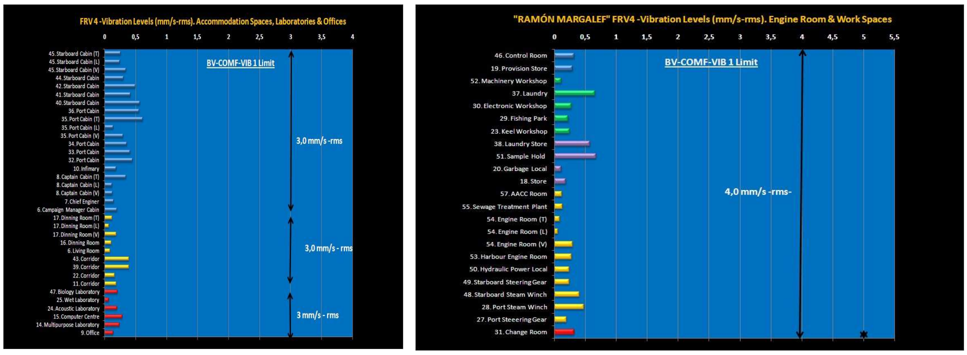


Figure 9.- "<u>*Ramón Margalef*" Vibration on board: Accommodation and Engine Room spaces</u>**.-**

For a total of 36 locations at the Accommodation and Laboratory/Public spaces the Vibration on board average achieves a significant value of ***-2,7 mm/s-rms, LOWER*** than the corresponding BV-COMF VIB 1 limit (3 mm/s-rms). A Special mention must be done again for the Vibration levels at 23 locations in the Engine Room and in the Machinery spaces with an average deviation of ***-3,7 mm/s-rms***, when compared with the corresponding BV-COMF VIB 1 (4 mm/s-rms). All these values are a clear indicator of the low vibrational energy distribution achieved along the vessel's structure due to the preventive actions adopted.

<u>Noise Radiated to Harbour (NRH)</u>.

The corresponding results related to this topic are reported in **Figure 10** and were carried out in the framework of the On-site Measurements activities of the SILENV project. As it can be seen the outdoor noise levels at 20 m of the starboard hull-side along all the length of the *"Ramón Margalef"* are below 65 dB (A), according to the Preliminary SILENV limits adopted as well as the limits established by Directive 2006/87 EC and by ISO 2922/200 Acoustic **[15].**

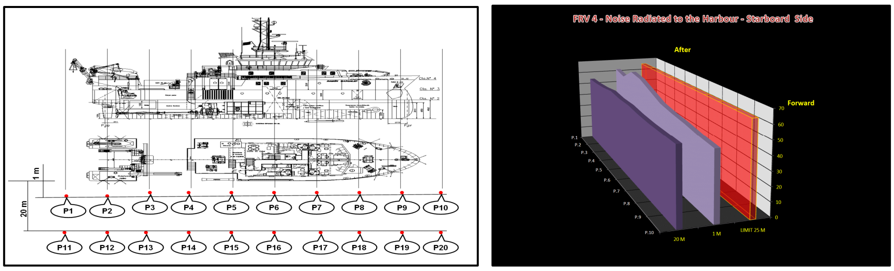
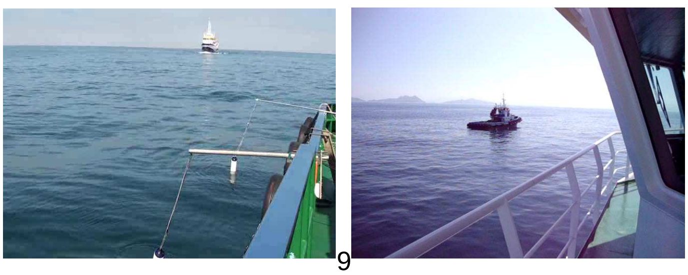


Figure 10.- "<u>*Ramón Margalef*" Starboard hull side Outdoor Noise levels</u>**.-**

<u>Underwater Radiated Noise (URN)</u>.

A sequence of the URN Measurements tests and the results obtained in terms of URN Pressure (ref 1µPa) @ 1m 1/3 Octave Band Spectra (1 Hz) at an operational speed of 11 knots, for both hull sides, are reported in **Figure 11**.



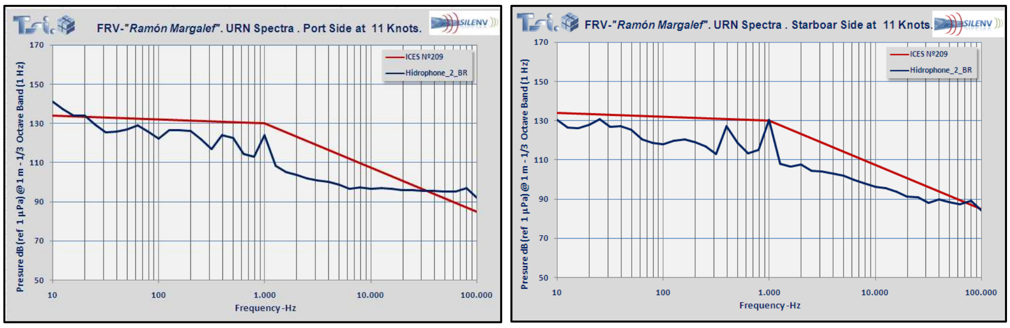


Figure 11.- "<u>*Ramón Margalef*" URN Measurements & URN 1/3 Octave Band Spectra @ 11 Knots</u>**.-**

The exam of the previous **Figure 11** enables us to state that the FRV "*Ramón Margalef*" complies with the ICES Nº 209 Regulation **[9]**. The narrow band analysis has permitted to prove and confirm that the small deviations observed at low and high frequencies are not related to URN sources but to the disturbance that the measuring device suffered because of the sea state and because of some interference that came from a meteorological sound-boy that was operating in the area.
Finally, as a complementary *"external indicator"* of the low underwater footprint of the FRV "*Ramón Margalef*", **Figure 12** below, shows the "high resolution and spectacular definition" of the data obtained by the IEO´s Scientifics (courtesy of SIMRAD/ KONSBERG) with the on board echo-sounders, during the geological research carried out by the vessel in its first investigation about the sudden appearance of a new volcano in the coast of "El Hierro Island" (Canary Islands-Spain).

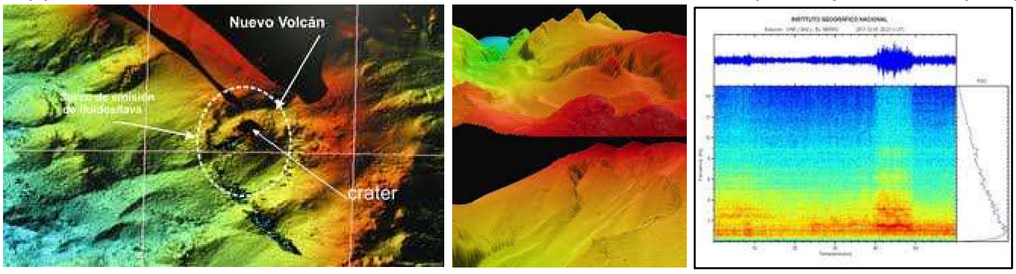


Figure 12.- "<u>*Ramón Margalef*". Geological data appearance of new volcano (SIMRAD´s courtesy)</u>**.-**

4 CONCLUSIONS: *"LESSONS LEARNT".*

Some of the most interesting Conclusions and Lessons learnt, according to our judgement, are detailed in the following paragraphs:

- Based on the experimental results obtained, the FRV "***Ramón Margalef***" has become one of the most *"silent vessels"* of the European Fleet, and so with less environmental impact. It is also a milestone and an indicator that the European Shipbuilding Industry and so, the Spanish one too, is capable of attending the current needs and of constructing vessels that comply with the most strict environmental requirements in the framework of the new EC Green Policy.
- The "*Ramón Margalef*", is another successful vessel that is now included in the wide portfolio of silent vessels that the authors have designed, and permits to verify once and for ever that the methodology of *"N&V Integrated Management"* applied, should be considered as a "practical guide" that should be followed up for the design and construction of *"silent vessels".* Not only for FRV but also for commercial ones. The other mentioned factors cost/benefit ratio, fuel efficiency and technical viability should also be considered and properly weighted.
- Once these two essential pillars: Shipbuilding capabilities and the availability of successful "Practical Guides", have been consolidated, the *"battle against the high noise in the Oceans"* requires, from the author´s point of view, the establishment of clear, well-founded and coordinated policies based on the following points:
  - <u>*Technological*</u>: Harmonization of the measurement procedures and improvements in the measurements devices and in the acquisition and post-processing process, are essential. The

precise identification of the *"enemies"* (URN sources), in order to properly attack them, will not be submitted to "unsupported assertions" but based on consistent experimental results.

- o *Preliminary Limits Definition*: The target is *"to reduce the underwater noise for protecting the marine fauna"*. Two key questions arise and need to be answered: *How much must we reduce the noise?* (Unfeasible for the current fleet); and *How much will it cost for a new vessel?* A first consensus between the Scientific community and the Shipbuilding Industry is essential if some Preliminary URN Limits want to be defined. Perhaps these Preliminary limits are not as strict as many Biologists would like, but they will oblige the Shipbuilding Industry, to move ahead and to assess the impact that the achievement of these limits has on the costs, and so their technical-economic viability.
- o *Regulatory Framework*: The complete absence of URN requirements in the contract specifications has been confirmed as the main cause of URN data unavailability. The premise *"no one does nothing if they are not forced to"* is well stated. This status needs to be changed, and for changing the following actions must be carried out: *Firstly*, there should be a thorough dissemination of the EC policy within the Marine Sector (currently immerse in a "hard crisis") focused on not *"forcing"* but "convincing", about the advantages of fighting against the URN impact. *Secondly*, the absence of URN data for most of the current fleet made impossible the suitable "URN Management" and the identification of which vessels should not enter protected areas. The URN signatures from a representative sample of vessels are therefore needed, independently of the compliance with whichever the URN limits are. The same criteria should be applied for the new constructions.

- Finally the EC has to know that the retrofitting of old vessels in order to reduce the current underwater noise levels is technically and economically unfeasible. Fleet renewal must be based on the full compliance with the "Environmental Requirements: Emissions, Fuel consumption reduction and N&V".

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