



Discussion Paper Noise

INTRODUCTION

Hearing loss, as a result of exposure to noise, is one of the most common occupational diseases.

It is the second most self-reported occupational illness or injury; however it should be entirely preventable.

Noise levels can have a positive or negative effect on crew members.

Adverse noise levels can contribute to noise induced hearing loss, cause speech interference, mask signals, interfere with concentration and thought processes, disrupt sleep, and cause fatigue and aggression. Noise has also been associated with uncertainty and lack of self-confidence, irritation, misunderstandings, and problems in human relations which could lead to decreased working capacity (Lazarus 1998). In contrast, appropriate noise levels may provide an environment for improved crew performance, increase communication, have a positive psychological effect on crew members, and enhance crew comfort enabling the crew to use a space for its intended purpose with minimal interference from noise.

Noise is defined as an undesired sound or an erratic, intermittent, or statistically random oscillation.

TERMS/DEFINITIONS

Decibel (dB): A unit of measurement of loudness or strength of a signal. A decibel is a logarithmic scale of loudness. A difference of 1 decibel is the minimum perceptible change in volume; 3 dB is a moderate change; 10 dB is a doubling of volume.

Duration: The length of sound exposure.

Frequency: The number of repetitions of a periodic phenomenon within a unit of time. Frequency is given in Hertz (Hz) equivalent to cycles per second (cps). It is represented in how high or low pitched the noise is.

Intensity of noise: The loudness of a sound.

Noise: An undesired sound or an erratic, intermittent, or statistically random oscillation.

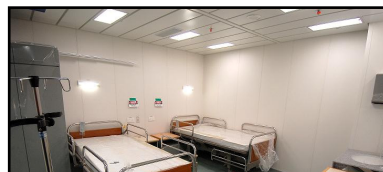
Noise Level: Noise levels in this document refer to the sound pressure levels that describe a particular noise environment.

Noise reduction (NR): The difference in dB between the sound pressure levels on different sides of a boundary construction. Noise reduction can also refer to the number of dB by which sound pressure levels are reduced in a single space or at a fixed location due to introduction of noise control treatments. Unlike

transmission loss, noise reduction depends not only on the intervening structure but also on source and receiver room acoustic properties.

Sound pressure (SP): The local pressure deviation from the ambient pressure caused by a sound wave.

Manned crew space: A space is considered "manned" when it is occupied by crew members for twenty (20) minutes or longer time during standard routine daily activities.



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DISCUSSION

Effects of Auditory Noise

Adverse/improper noise levels may negatively affect crew activities in several ways. They may:

- Contribute to noise induced hearing loss
- Interfere with speech communications
- Interfere with signal detection
- Interfere with concentration, thought processes, and other cognitive performance
- Disrupt sleep
- Contribute to fatigue and aggression
- Contribute to uncertainty, lack of self-confidence, irritation, misunderstandings, and problems in human relations which can lead to decreased working capacity (Lazarus 1998)



Various regulations, methods of measurement, and treatments are applied to control noise levels which mitigate the negative effects.

Noise Regulations

There are many basic approaches to noise regulation. The two most often invoked involve hearing loss avoidance (hearing conservation) and crew comfort. Others address the hearing of alarms, communications, environments allowing sleep (non-awaking) and avoidance of harmful physiological impacts (stress, performance, etc.).



Hearing conservation typically involves an A-weighted time-averaged sound exposure limit. This is a measure of noise exposure that is an average of varying levels of noise experienced in a given time period. IMO Resolution A.468(XII) (1981) *Code on Noise Levels On-board Ships* should be followed for noise levels and exposure duration, particularly for areas where noise levels exceed 85 dB(A). The inherent assumption is 8 hours of work exposure in a high noise environment and 16 hours of very low noise exposures. This is not the situation onboard vessels and, as a result, USCG has

recommended a 24-hour exposure limit, $L_{Aeq,24}$ of 82 dB(A) for the seafarer. To put this exposure limit in context: the noise of a jet plane taking off is 120 dB, and that of a vacuum cleaner is 70dB. The noise levels defined are for sea-going conditions only.

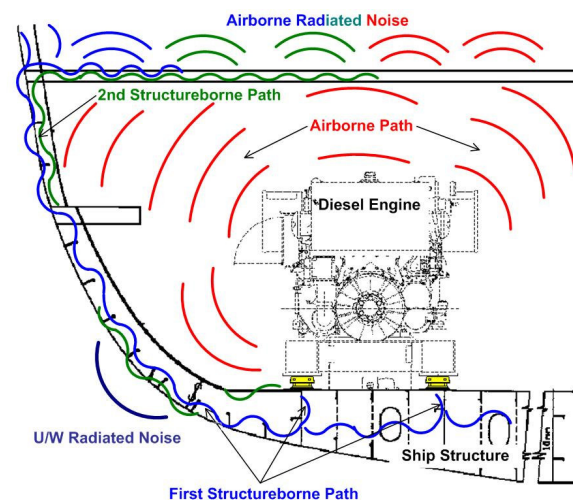
Noise level exposure varies between crewmembers. For example, the crew working in the engine room is exposed to higher noise levels than the crew working on the bridge. The exposure measurements therefore need to take into account the different roles of crewmembers.

Crew comfort (and by implication performance, alertness, etc.) is typically approached by setting noise limits in compartments (manned crew spaces) on the basis of the function of the space. For example, the berths have lower noise limits than work spaces; machinery spaces higher limits than workshops. This is the basis for the compartment limits established for **HAB** and **HAB+**. In some cases the noise limits depend on the function or operation of the vessel (ABS 2001, 2007, 2008).

Overview of Shipboard Noise

To effectively analyze and control shipboard noise, the ‘source-path-receiver’ phenomena should be fully understood. To perform a noise prediction analysis and to optimize the selection of treatments to meet a certain noise criteria, we must consider the following parameters:

- The acoustic *source* level of the noise producer
- How this energy gets to the receiver via airborne, structure-borne, and fluid-borne *paths*
- How the acoustic characteristics of the *receiver* space affect the resulting noise levels



This process is involved, since the parameters change drastically with the frequency, and the composition of the vessel between the various sources, paths, and multiple receivers. Noise is transmitted from a source location to a receiver area over the air media (airborne) and through the ship structure (structure-borne) before the sound reaches the receiver area. The receiver can be inside or outside the vessel, in the equipment room, or remote from the equipment.

Structure-borne noise results from radiation by vibrating surfaces (deck, bulkheads, deckhead, etc.) within the compartment of interest. Vibration is

transmitted by different types of waves. Due to the nature of these structural waves, the structure-borne energy is partially transmitted from obstacles, and part of the energy is dissipated by conversion to heat and radiation along the source-to-receiver path. The obstacles for structure-borne noise are the deck/bulkhead intersections, frames, and other non-uniformities in the structure. With a greater number of obstacles along the path, the noise reaching the receiver space is lower.

The acoustical characteristics of a receiver space control the level of the received noise transmitted over a path, whether airborne or structure-borne. Three basic types of receiver spaces are considered:

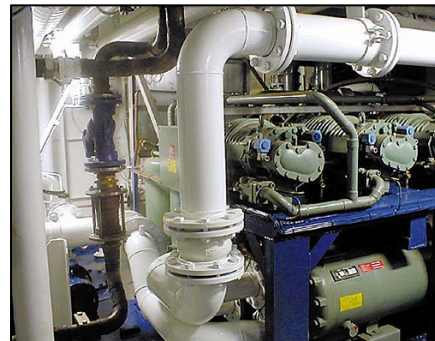
- Those containing a source of noise
- Those without an internal noise source
- Those adjacent to a machinery space

Sources of Noise

Machinery

Typical shipboard noise sources include the main and auxiliary engines, pumps, compressors, fans, and other equipment located in a machinery space. These sources generally generate significant source noise and vibration levels, particularly in the vicinity of engine rooms. Main engine intake and exhaust systems often generate high noise level at on-deck stations and, at times, inside the vessel's manned compartments.

The acoustic source may generate 'airborne' noise. Noise emanating from the casing of any mechanical source, intake/exhaust, or from fans is generally considered 'airborne' noise. 'Airborne' noise is the most critical type of noise within a machinery space and the compartments directly adjacent to the machinery space.



The rest of the vessel is affected by 'structure-borne' noise generated by the acoustic source via its attachment point to its foundation. Depending on the level of treatment, secondary structure-borne noise (a combination of the airborne source level and the response of the structure inside the machinery space itself) may also be important in spaces remote from the machinery.

The best noise models and noise control solutions *critically* depend on defining and understanding 'airborne' and 'structure-borne' noise as two discrete sources for the same unit.

Machinery noise and vibration source levels, in general, scale with the equipment power, rpm, and weight. Although empirical methods exist to predict noise

source levels, measured data from the vendor or from similar equipment from a previous project is preferable. Noise source levels are measured at a predetermined distance from the unit (usually 1 m (3.3 ft)) and are used for the airborne source characterization needed for acoustic modeling. It is best to determine these levels in octave bands so they can be used as input data for a detailed noise analysis.

Heating, Ventilation, Air Conditioning (HVAC)

As a distributed system, the HVAC can be an important contributor to manned compartments and work spaces. Ventilation ducts and unit coolers may create high noise levels throughout the vessel. As a rule, ventilation noise is a combination of aerodynamic (fan and flow regenerated) and mechanical noise. Similarly, ventilation systems can be of concern, particularly on-deck or in machinery spaces with the internal equipment secured. Note that more than any other system, HVAC-induced noise can be abated or reduced by following good acoustic design practices. The general objective is generally to ensure that the HVAC-induced noise is at least 5 dB below the compartment's noise limit.

Propulsion System

Noise sources may also be located outside the ship. Propellers, thrusters, water jets, and other hull protrusions fall in a category of 'hydro-acoustic' sources. The propulsors generate relatively high sound pressure level in water around the blades. This high sound pressure in-water induces vibration on the hull (bottom shell or thruster tunnel), while part of acoustical energy may travel through the hub and shafts as well.

Piping and Other Sources

While not as distributed as an HVAC system, piping systems can be an important contributor to compartments near the machinery space (e.g., the control room). Hydraulic systems, especially those with distributed piping runs, can produce annoying noise at the pump pulsation rate. In this case, the fluid-borne noise in the piping couples to vibration in the pipe wall. This pipe wall vibration is transmitted as structure-borne noise at the piping supports.



Ice, waves, and inflow interaction with the hull may be additional significant noise sources in the bow and aft compartments of some ships and should be evaluated. The more stringent the noise limit, the more critical these sources become. Electronic equipment and their cooling systems may be significant sources of noise in noise critical compartments such as the Radio Room and Pilothouse.

Modeling Shipboard Noise

Without an accurate model of shipboard noise it is difficult to optimally select the appropriate noise control treatments. It has been shown on numerous projects. Acoustical modeling during the project design stage may save a great deal of time, money, and labor, and helps to avoid after construction corrections. Retrofitting treatment may be ten times more expensive than incorporating treatments in the design process. Any model includes the following components:

- Source description
- Acoustic path description – basically the ship's construction
- Receiver space description – including insulation and sheathing

Measuring Noise

Noise can be measured by sound level meters, noise dosimeters, octave band analyzers, and sound intensity analyzers. The sound level meter (SLM) is the basic instrument for investigating noise levels. It can be used to evaluate area noise levels, identify noise sources, estimate crew member exposures, and aid in determining solutions for noise control.



In the United States, the American National Standards Institute (ANSI) classifies levels of precision for sound level meters as Type 0 (laboratory standard), Type I (precision measurements in the field), and Type II (general purpose measurements). The Type II meter is most frequently used in the field for personnel exposure and noise evaluation purposes.

A noise dosimeter is essentially an SLM that integrates noise levels over the sampling period and calculates the noise dose. It is the primary instrument used for compliance measurements. The noise dosimeter is worn by an individual during sampling to calculate personal noise dose, or it can be placed in a specific location to measure the sound level in that area.

An octave band analyzer is a type of SLM which can separate the monitored noise into specific frequency bands, which is necessary when analyzing noise sources to develop noise control solutions. This information is also useful in selecting hearing protectors by calculating the amount of attenuation for specific frequency bands. Most octave band analyzers filter the sampled noise spectrum into 9 or 10 octave bands, while some analyzers can measure noise in one-third octave bands for an even more detailed analysis. Usually, a Type I (precision) SLM is used for octave band analysis.

Ordinary SLMs measure sound pressure level, which indicates the level of the sound, but not the direction from which the sound is coming. A sound intensity analyzer can measure intensity, which is a measure of both the magnitude and direction of the sound energy. This analysis can often be performed in

environments where the noise is reverberant, since the intensity analyzer indicates the direction of the noise. A sound intensity analyzer is particularly useful for pinpointing noise sources and determining appropriate engineering controls.

Noise Treatments

Where crew have to work in areas with high noise levels, their job design should be reviewed and changed appropriately so they have less exposure in these hazardous areas. Wearing PPE to protect against excessive high noise levels shall always be the last option to be considered. If PPE has to be worn, then clear signage warning crew to wear PPE must be erected in the hazardous areas.

Where possible, excessive noise should always be designed and engineered out at the source. The most effective noise control method is to specify and select equipment with inherently low noise and/or vibration source levels. Equipment with a low source level may eliminate the need for extensive treatments. Of course there will always be the trade-off between noise and weight, cost and operation of the vessel.



Effective treatment exists for abating noise generated by a source, along a particular path, or in the receiver space. Different treatments may be needed to reduce airborne sources, structure-borne sources, airborne paths, structure-borne paths, HVAC induced noise, etc.

There are various ways to reduce noise by engineering means, which include:

- Use of alternative materials for the noise source
- Use of silencers
- Use of acoustic lagging
- Use of sound enclosures
- Use of mounts

Each treatment type depends on an understanding of the prevailing airborne or structure-borne noise components.

When treatments become necessary, the optimal treatment choice should be based on an accurate noise prediction with a separation between airborne and structure-borne noise contribution. Propulsion engines and other machinery, HVAC, propulsors, piping systems, noise paths, noise receivers, etc. should all be considered for noise treatments.

As a rule, the main propulsion machinery space is the noisiest compartment shipboard. Diesels or gas (steam) turbines are the usual choice as propulsion engines for most vessels. Marine gas turbines are sometimes supplied with an



acoustical enclosure. An enclosed gas turbine has 10 to 20 dB lower airborne noise levels than an equivalent diesel. Though not the rule, an acoustical enclosure can be provided for diesels, particularly for diesel-generator sets; and some diesel vendors provide 'quiet' diesel through the installation of factory fitted noise shields. In all cases, maintainers need to be particularly cautious to excessive high noise levels when removing noise-abating structures for maintenance purposes.

If a propulsion diesel is hard mounted, structure-borne noise is usually higher than the airborne noise levels caused by the diesel in an adjacent compartment. The most effective treatment in this case is a resilient mounting system. The alternative to isolation mounting is extensive application of damping material, floating floors, and isolated joiner paneling.

The largest consideration for other machinery such as compressors, pumps, and fans is whether isolation mounting of the equipment is more effective than path and receiver treatments to abate the noise. Typically, if only one or two machinery items are the primary source of received noise in multiple locations, treatment of the source is most effective. When there are numerous sources and they are well distributed, then receiver treatments (noise abatement not at the source, but an away operating station) are generally the most effective approach. The path treatment generally considered is damping.

System Design Guidance

Noise control on ships is a part of the design and construction process and should be iterated from the concept design stage through acceptance trials. Any Noise Control Plan should address both a management approach and an engineering approach. A typical noise control plan should include a systematic approach to noise control from design through verification testing.

Management Approach

The noise control process requires clear organization and management. The shipyard should assign a Noise Control Manager who works as a liaison between the design group, the acoustical consultant, and the production and quality assurance group. Acoustical design is an iterative process; sometimes noise treatments may contradict cost/weight/safety issues. The Noise Control Manager should resolve contradictions jointly with the project manager, the project engineer, and the acoustical design group or acoustical consultant.

Based on the iterative noise analysis during the design process, the Noise Control Manager should be involved in assigning material, machinery vendors, and subcontractors. Tentative schedules should be developed for internal and external design review meetings, analyses, design deliverables, construction inspections, and trials. Particular attention should be paid to major changes in hull structure that could have a potential impact on acoustic performance. The



shipyard should develop and submit pertinent schedule/milestone information and identify deliverables as per the specification.

Engineering Approach

The engineering approach to a Noise Control Plan may include the following five phases:

1. Design review, noise prediction, primary treatment selection for concept, preliminary and contract design stage
2. Revisions of noise treatments during detailed design
3. Consideration of non-acoustic impacts
4. Treatment implementation and evaluation
5. Trial and documentation

SUMMARY

Acoustic Design Guidance can be used to minimize noise in crew areas aboard ships. A detailed noise analysis will reveal the critical sources and acoustic transmission paths. With this detailed understanding of the potential problem areas, the selection of appropriate and optimal treatments can be conducted with confidence. These treatments need to be incorporated into the design stage and installed in the vessel. Treatments should be inspected to make sure they are installed properly. Controlling noise in design can be accomplished through a combination of management and engineering approaches and can lead to successful vessel noise control implementation.

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