



GUIDANCE NOTES ON

ONBOARD SHIP NOISE ANALYSIS

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Foreword

These Guidance Notes provide an overview of and specific guidance on onboard ship noise analysis methodologies.

There is an increased demand for onboard ship noise analysis due to several industry requirements relating to noise exposure levels for seafarers. These include the International Labour Organization's (ILO) Maritime Labour Convention (MLC), 2006 and the IMO Code on Noise, which came into force in July 2014. To support ship designers and builders in improving the acoustic design of their ships, ABS has developed these Guidance Notes and has offered noise analysis services for years.

Included in these Guidance Notes are commonly-used modeling and analysis methods, as well as the basic concepts for the evaluation of noise analyses. These Guidance Notes can be used to assist in the noise analysis for ocean-going vessels.

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CONTENTS

SECTION 1	General	1
1	Introduction	1
3	Application	1
5	Scope	1
7	Relevant Documents	2
9	Terminology	2
SECTION 2	Source-Path-Receiver Modeling	4
1	Overview	4
3	Source	5
3.1	Overview	5
3.3	Machinery	5
3.5	Propulsion	7
3.7	Ventilation Fans	9
5	Sound Transmission Path	9
5.1	Airborne Path	10
5.3	Structure-borne Path	11
5.5	Duct-borne Path	13
5.7	Fluid Load	14
5.9	Path Simplification	14
7	Receiver	15
7.1	Radiation Efficiency	15
7.3	Room Constant	16
TABLE 1	Airborne Sound Transmission Loss of Typical Ship Panels	11
TABLE 2	Damping Loss Factor for Typical Hull Structures	12
TABLE 3	Damping Loss Factor for Two Types of Damping	12
TABLE 4	Radiation Efficiency of Typical Ship Structures, $10\log \sigma_{rad}$	15
TABLE 5	Acoustic Absorption Coefficients of Typical Materials	16
FIGURE 1	Noise Transmission Flow Chart	4
FIGURE 2	Noise Sources on Board Ships	5
FIGURE 3	Resilient Mount and Foundation Arrangement	7
FIGURE 4	Calculation Procedure for Propeller Induced Vibration	8
FIGURE 5	Sound Transmission through Compartments	10

FIGURE 6	Typical Configuration of Floating Floor	13
FIGURE 7	Sound Transmission via HVAC Ducts	14
FIGURE 8	Type A Vessel – Accommodation Area in Fore Part	15
FIGURE 9	Type B Vessel – Accommodation Area in Aft Part	15
SECTION 3	Results Evaluation	17
1	Frequency Analysis and Octave Bands	17
3	A-weighting Evaluation	17
5	Criteria.....	18
5.1	ABS Criteria.....	18
5.3	ILO MLC 2006 and IMO Noise Code	18
TABLE 1	A-filter Values.....	18
TABLE 2	Noise Level Limits, dB(A).....	19
FIGURE 1	A-Weighting Filtering Curve	18
APPENDIX 1	Empirical Method.....	20
1	Airborne Sound Transmission.....	20
1.1	Airborne Sound Transmission in Source Room.....	20
1.3	Airborne Sound Transmission Loss through a Partition.....	20
1.5	Airborne Sound Transmission through Large Openings	21
3	Structure-borne Sound Transmission	21
3.1	Within the Source Room.....	22
3.3	Beyond Source Room.....	22
3.5	Intersections	23
5	Duct-borne Sound Transmission	23
5.1	Plenum	23
5.3	Silencers.....	23
5.5	Straight Duct Attenuation.....	24
5.7	Branches	24
5.9	Turns	25
5.11	End Reflections at Duct Openings	25
TABLE 1	Approximate Attenuation of Typical Silencers, in dB	24
TABLE 2	β , Attenuation, in dB per Meter of Duct Length.....	24
TABLE 3	β , Attenuation, in dB per Feet of Duct Length.....	24
TABLE 4	Attenuation for Turns, in dB	25
FIGURE 1	Directivity Factors Q	20
FIGURE 2	Incident Angle	21
FIGURE 3	Source Room Layout	22
FIGURE 4	Structure-borne Sound Transmission Path in Ship Structures.....	23

APPENDIX 2	Statistical Energy Analysis (SEA) Method	26
1	Overview	26
3	Energy Flow Relationships	27
	FIGURE 1 Acoustical Power Flow between Two Subsystems.....	27
APPENDIX 3	References	29

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SECTION 1 General

1 Introduction

Noise on board ships has seen increased attention in recent years. Excessive noise levels on board ships can adversely affect the task performance and health of seafarers. Seafarers may become distracted if exposed to high noise and vibration levels and this can increase the potential for human error. Prolonged exposure to high-noise environments can lead to long-term health issues such as noise-induced hearing loss. It is expensive and difficult to fix noise-related issues after construction. Therefore, it is important and necessary for ship designers and builders to perform noise analyses and address these concerns at an early design stage. ABS has offered noise analysis service for years.

For onboard ship noise analyses, the commonly adopted “Source-Path-Receiver” modeling technique may be used. This modeling scheme takes three key elements into consideration: noise sources, transmission paths, and the receiver acoustic characteristics. Empirical methods and numerical analysis methods can be used to calculate the sound attenuation from “Sources” to “Receivers” through different transmission “Paths”. Various empirical methods have been developed. For example, The Society of Naval Architects and Marine Engineers (SNAME) published the *Design Guide for Shipboard Airborne Noise Control* ^[1], which provides a step-by-step empirical method to predict onboard ship noise levels. For the numerical analysis method, the statistical energy analysis (SEA) method is one of the more effective methods to predict onboard ship noise levels. It is efficient in addressing noise issues in complex structures at high frequencies.

3 Application

These Guidance Notes can be used to assist in the noise analysis for ocean-going vessels.

5 Scope

In these Guidance Notes, the following topics are discussed:

- i) Source-Path-Receiver Modeling
- ii) Results Evaluation
- iii) Empirical Method
- iv) SEA Method

The Source-Path-Receiver Modeling in Section 2 provides an overview of the modeling method of onboard ship noise analysis. It introduces methods for the modeling of the noise source, transmission path, and the receiver room.

The Results Evaluation in Section 3 provides the basic concepts of evaluating the results of the noise analyses. It introduces the concept of frequency band analysis and the most widely-used weighting method, A-weighting method, to consider the sensitivity of the human ear.

The Empirical Method in Appendix 1 provides the empirical formulae for the calculation of transmission attenuation from airborne sound, structure-borne sound, and duct-borne sound.

The SEA Method in Appendix 2 introduces the general concepts of SEA, which is a widely-used numerical method for onboard ship noise analysis.

7 Relevant Documents

- *ABS Guidance Notes on Noise and Vibration Control for Inhabited Spaces*
- *ABS Guide for Crew Habitability on Ships*
- *ABS Guide for Crew Habitability on Workboats*
- *ABS Guide for Habitability of Industrial Personnel on Accommodation Vessels*
- *ABS Guide for Passenger Comfort on Ships*
- *ABS Guide for Comfort on Yachts*
- *ABS Guide for Compliance with the ILO Marine Labour Convention, 2006 Title 3 Requirements*

9 Terminology

Acceleration. A vector that specifies the time rate of change of velocity (units of $\text{m/s}^2(\text{ft/s}^2)$). The acceleration of the vibratory motion of a structure can be specified in terms of the peak, average, or root-mean-square (rms) magnitude of the acceleration in a given direction. In this document, the acceleration levels are given in terms of the rms acceleration amplitude.

Airborne Sound (or Noise). Sound or noise that is transmitted through air.

A-weighted Sound Pressure Level. The magnitude of a sound, expressed in decibels (i.e., 20 micropascals); the various frequency components are adjusted according to the A-weighted values given in IEC 61672.1 (2004) in order to account for the frequency response characteristics of the human ear. The symbol is L_A , and the unit is dB(A). The measurement L_{Aeq} is an equivalent continuous A-weighted sound pressure level, measured over a period of time.

Cavitation Inception Speed. Vessel speed at which a propeller starts to cavitate.

Control Volume. A volume moving with constant flow velocity through which the continuum acoustic energy flows.

Coupling Loss Factor. It is a parameter unique to statistical energy analysis (SEA), which measures the rate of the energy flowing out of a subsystem through a junction to another subsystem.

Damping. The dissipation of energy with time or distance. In this document, damping generally refers to dissipation of vibrating energy in structures.

Damping Loss Factor. A parameter indicating the ability to dissipate the sound energy within the structures.

Decibel (dB). A dimensionless unit of measure of the ratio of two quantities, P_1 and P_2 , each of which is equal to or proportional to power. Ten times the logarithm to the base 10 of the ratio, P_1/P_2 , has the dimensions of dB.

Directivity. A measure of the directional characteristic of a sound source.

Direct Sound Field. A sound field in which energy is flowing outward from the source without interference from surrounding surfaces. The sound field very close to a source, even in a reverberant room, is a direct field. Sound fields outdoors are direct fields at all distances from the source and are referred to as “free sound fields” or “free fields”.

Dynamic Positioning (DP). A system to automatically maintain a vessel’s position and heading by controlling propellers and/or thrusters. Dynamic positioning can maintain a position to a fixed point over the bottom, or in relation to a moving object (such as another vessel). It can also be used to position the vessel at a favorable angle towards wind, waves, and current.

Excitation. A time-dependent stimulus (force or displacement) that produces vibration. Excitation may be transient, random, and periodic. A steady-state periodic excitation, like that produced by propellers or propulsion engine, is of interest in these Guidance Notes.

Free Field. A sound field in a homogeneous, isotropic medium free from boundaries. The sound pressure level decreases by 6 dB per doubling of distance from the source.

Free Velocity Level. The velocity level of the machine measured when it is mounted on sufficiently soft isolators on a sufficiently stiff and heavy foundation.

Frequency. The number of complete cycles of a periodic process occurring per unit time. Frequency is expressed in Hertz (Hz), which corresponds to the number of cycles observed-per-second.

Frequency Band. An interval of the frequency spectrum defined between upper and lower “cut-off” frequencies. The band may be described in terms of these two frequencies, by the width of the band, and by the geometric mean frequency of the upper and lower cut-off frequencies (e.g., “an octave band centered at 500 Hz”).

Joiner Panel. The inner side outfitting of the compartment, which covers the bulkhead and insulation.

Level. In acoustics, the level of a quantity is the logarithm of the ratio of that quantity to a reference quantity of the same kind. The base of the logarithm, the reference quantity, and the kind of level need to be specified. Examples are sound power levels, sound pressure levels, and acceleration levels. Levels are always expressed in decibels (dB).

Mass Law. The relationship between sound transmission loss and weight of the barrier. The mass law states that for every doubling of the weight of the material, a 6 dB increase in the transmission loss can be expected.

Modal Density. Number of modes per Hertz.

Octave Band. The frequency range bounded by upper and lower frequency limits f_u and f_l , where $f_u = 2f_l$. Octave bands are usually specified by their geometric mean frequency, called the band center frequencies. The standard octave bands covering the audible range are designated by the following center frequencies: 31.5, 63, 125, 250, 500, 1000, 2000, 4000, 8000, and 16,000 Hz. The corresponding lower and upper frequencies are 22/45, 45/89, 89/177, 177/354, 354/708, 708/1416, 1416/2832, 2832/5664, 5664/11,328, 11,328/22,656.

Radiation Efficiency. The radiation efficiency of a vibrating surface is proportional to the acoustic power radiated per unit surface area per unit of mean-square velocity of vibration averaged over the radiating surface. It is the measure of the efficiency with which a given surface converts vibratory energy to acoustic energy.

Reverberant Sound Field. The part of the radiated sound field where the sound waves reflected from the boundaries of the enclosure are superimposed upon the incident field. The reverberant field may be called a diffuse field if a great many reflected wave trains cross from all possible directions and the sound-energy density is very nearly uniform throughout the field.

Statistical Energy Analysis. A numerical method for predicting the transmission of sound and vibration through structural acoustic systems. SEA method calculates the average response of the structure and avoids a large quantity of calculation, which is efficient for large and complex structures.

Sound Power. The rate at which sound energy is emitted, reflected, transmitted or received, per unit time.

Sound Pressure Level. SPL, in dB, is 20 times the logarithm to the base 10 of the ratio of the pressure of this sound to a reference pressure. The sound pressure, p , is the root-mean-square value of the instantaneous sound pressure over a time interval at the point under consideration.

Static Pressure. The pressure difference of air when flowing across a fan.

Structure-borne Sound (or Noise). Sound or noise that is transmitted through structures that are capable of supporting shear. Thus, structure-borne sound may be in the form of longitudinal or flexural waves.

Transmission Loss. The sound transmission loss (TL) of a partition, in dB, is the difference between the incident sound intensity level and transmitted sound intensity level. It can be expressed as 10 times the logarithm to the base 10 of the reciprocal of the transmission coefficient, τ .

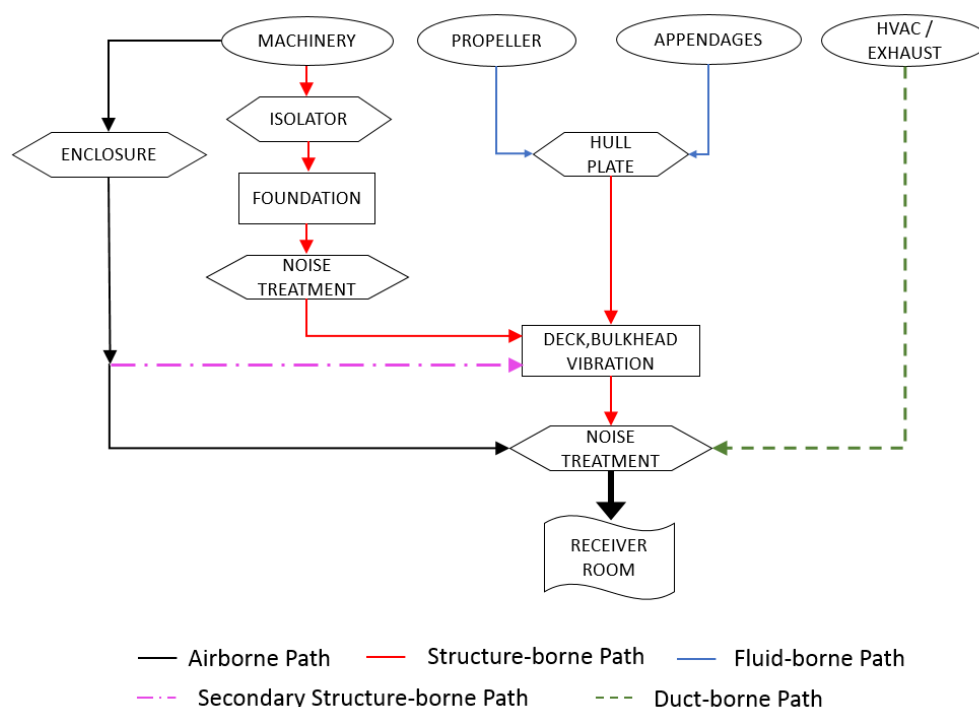
Transit Condition. Those conditions where the vessel is transiting (moving) from one location to another.

SECTION 2 Source-Path-Receiver Modeling

1 Overview

The modeling of onboard ship noise analysis requires three key elements to be considered: “Source”, “Path”, and “Receiver”, and the procedure is described as Source-Path-Receiver modeling ^[1]. “Sources” are the equipment which generates airborne noise and structure-borne noise, such as main engines, propellers, compressors, and fans. “Paths” are the air, fluid, or solid structures such as decks and bulkheads through which sound propagates. “Receivers” are the compartments of interest, such as seafarer cabins, workspaces, and offices. The modeling of the receiver component addresses the location and the acoustic characteristics of these spaces. Section 2, Figure 1 is a flowchart of noise transmission from sources to receivers.

FIGURE 1
Noise Transmission Flow Chart

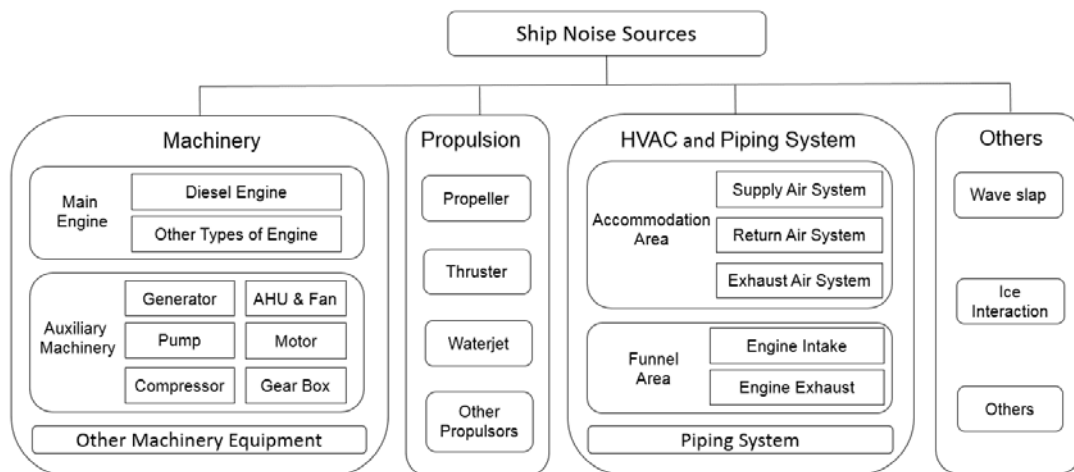


3 Source

3.1 Overview

Onboard noise sources include machinery, propulsion, heating, ventilation, and air-conditioning (HVAC) systems, piping systems, and environmental noise. Section 2, Figure 2 is an overview of noise sources on board ships. Each source can be dominant, depending on the source levels and the distance from the source(s) to the receiver room(s). Onboard noise prediction should take all dominant sources into consideration. Normally, onboard ship noise analyses considers propeller, main engine, generator, bow thruster, and the HVAC system. The need to consider other sources should be decided on a case-by-case basis. The use of actual measured source levels as the input excitation sources is recommended. When the measured noise or vibration source levels are not available, the source levels may be estimated by empirical formulae.

FIGURE 2
Noise Sources on Board Ships



3.3 Machinery

Typical machinery noise sources include main engines, diesel engines, generators, compressors, fans, and pumps. Among these machinery sources, main engine and diesel engines typically have the most significant effects on onboard ship noise levels. Each machinery noise source generates both airborne noise and structure-borne noise. Both the airborne noise and the structure-borne noise should be considered in noise analyses.

Airborne noise is usually the machinery casing noise. For main engines and diesel engines, besides the casing noise, airborne noise also includes the sounds emitting from air intakes and air exhausts. These noise sources could influence open deck areas and locations close to these openings. Airborne noise mainly influences the source room and the compartments adjacent to the source room.

Structure-borne noise is usually caused by machinery foundation vibration. Structure-borne noise could contribute to the noise levels in accommodation areas far away from the location of the machinery itself.

3.3.1 Machinery Casing Noise

Airborne noise levels can be expressed in terms of sound power level L_W or sound pressure level L_p , which are defined as:

$$L_W = 10 \log \frac{W}{W_0} \quad \text{dB}$$