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Ships and marine technology — Noise measurement method for HVAC system in accommodation spaces

Navires et technologie maritime — Méthode pour le mesurage du bruit du système CVCA dans les locaux

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Contents

Page

Foreword

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This document was prepared by Technical Committee ISO/TC 8, *Ships and marine technology*, Subcommittee SC 8, *Ship design*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Heating, ventilation and air conditioning (HVAC) is one of the most serious noise sources, especially for ship accommodation spaces that are far from the machinery spaces. This noise source affects the habitability comfort of crews and passengers on a ship. Although some standards exist for measuring noise on board vessels, for example ISO 2923, no special attention has been paid to measure noise arising from the HVAC. Other standards such as ISO 3740 are more accurate for quantifying measurement of a noise source. However, the methods specified in other standards require more measurement instruments, are more time-consuming than the method presented in this document and are difficult to use in the noise measurement of HVAC system onboard ships, which has many outlets distributed in hundreds of cabins.

This document specifies a method of noise measurement of HVAC systems in ship accommodation spaces by placing three microphones around the vent outlets to reduce airflow interference and space inhomogeneity, and by correcting the noise result by measuring the reverberation time of the cabin. The noise measurement method for the HVAC system is a compromise, which is more precise, but less laborious, compared to the previous methods.

The measurement should be performed for ship accommodation spaces, where noise exceeds the required limits according to existing regulations. The measurement and analysis results could be used to detect the causes of the higher noise level of the HVAC system, further enabling objective measures to be taken to mitigate these causes.

Ships and marine technology — Noise measurement method for HVAC system in accommodation spaces

1 Scope

This document provides the instrumentation requirements and measurement procedures for measuring noise from HVAC systems in ship accommodation spaces.

Accommodation spaces are defined according to ISO 2923, and include cabins, offices (for carrying out ship's business), hospitals, messrooms and recreation rooms.

Measurement of noise levels in HVAC systems in ship accommodation is performed in the third octave band over the frequency range from 63 Hz to 8 kHz, taking into account the correction of cabin reverberation.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 266, *Acoustics — Preferred frequencies*

ISO 3382-2, *Acoustics — Measurement of room acoustic parameters — Part 2: Reverberation time in ordinary rooms*

IEC 60942, *Electroacoustics — Sound calibrators*

IEC 61260-1, *Electroacoustics — Octave-band and fractional-octave-band filters — Part 1: Specifications*

IEC 61672-1, *Electroacoustics — Sound level meters — Part 1: Specifications*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
nose cone
microphone shield designed to substitute the normal protection grid of the microphone and used in high-velocity air flows with low turbulence and little swirl having a streamlined shape with the least possible resistance to airflow and a fine wire mesh around its periphery allowing sound pressure transmission to the microphone diaphragm, whilst a truncated cone behind the mesh reduces the air volume in the form of the diaphragm

Note 1 to entry: See Figure 1.

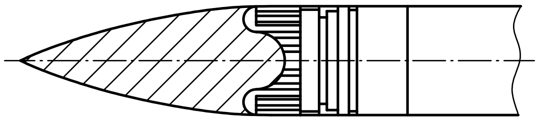


Figure 1 — Schematic diagram of a nose cone

3.2
windshield
device designed for the insertion of the microphone and preamplifier, taking the form of a ball of open-pored foam with a cylindrical hole of appropriate diameter and not to affect the directivity of the microphone

Note 1 to entry: A minimum size of the wind shield is suggested to diameter of 60 mm.

Note 2 to entry: See Figure 2.

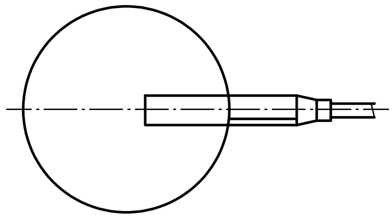


Figure 2 — Schematic diagram of a windshield

3.3
pink noise
random noise signal with a spectral density that decreases by 3 dB per octave, giving constant energy per octave

3.4
white noise
random noise signal having equal intensity at different frequencies, giving it a constant power spectral density

4 Instrumentation

4.1 Microphone with sound level meter or other microphone amplifier

A microphone combined with a sound level meter or other microphone amplifier shall be used, as required by IEC 61672-1 for a Class 1 sound level meter.

4.2 Microphone cable

The microphone cable shall meet the requirement that the sensitivity does not vary with temperature in the main range during the test. Disturbance of the cable, whether due to the traverse of the microphone or airflow across the cable, should not produce noise that interferes with the measurement.

4.3 Frequency analyser

The frequency analyser shall use a one-third-octave-band filter set as required by IEC 61260-1. The filter band centre frequencies shall be in accordance with ISO 266.

4.4 Nose cone and windshield

The use of a nose cone or windshield is desirable to offset the effect of air flow. The influence of nose cone and windshield on the measurement of noise levels shall not be greater than 0,5 dB (A). The combination of the nose cone and windshield with the microphone should be omni-directional.

4.5 Sound level recorder or other data sampling devices

Sound level recorders or other data sampling devices shall comply with the requirements of IEC 61672-1 for Class 1 instruments.

4.6 Calibration of instruments

The instruments shall be calibrated before and after each test by applying a Class 1 acoustic calibrator to the microphone in accordance with IEC 60942. The calibrator shall be calibrated within the interval specified by manufacturer.

5 General requirements

Noise level measurement should be carried out after the completion of the ship construction with all mechanical equipment switched off, unless necessary for running the HVAC system. If possible, the shore power in wharf condition or battery system should be used to avoid the influence of other mechanical equipment, such as diesel generator sets.

The HVAC system shall be in normal operation, its power shall meet the design conditions, and each exhaust outlet shall be adjusted in accordance with the designed flowrate.

Doors and windows should be closed tightly.

Noise generated by external sound sources, such as crew or passenger activities, recreation, construction and maintenance work, should not affect the noise value at the measurement site. If necessary, the measured values can be corrected according to the steady-state background noise.

When measuring the noise level, there should be no person except the measurement operator in the measuring accommodation spaces.

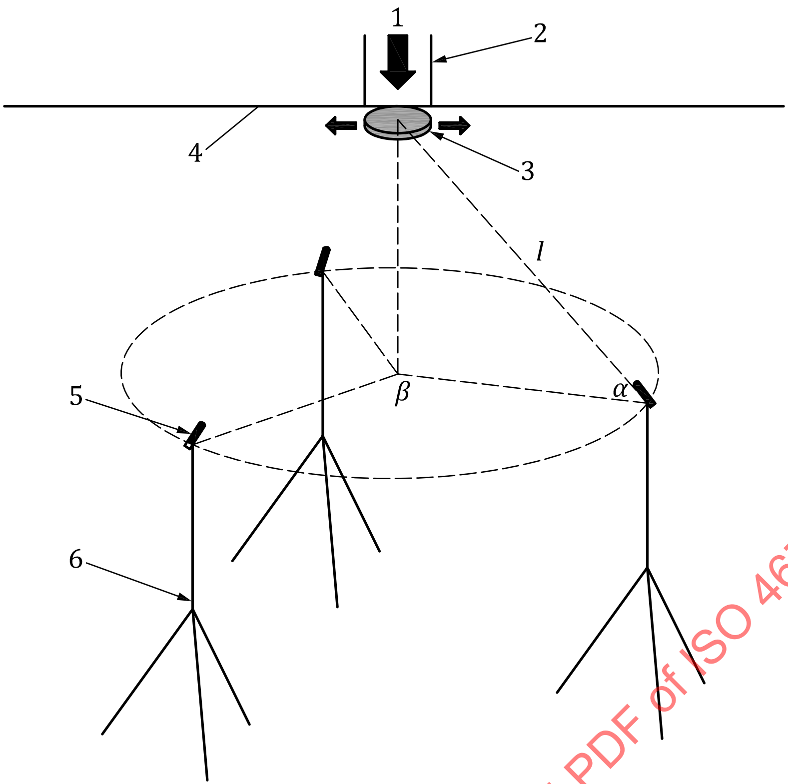
The noise level measurement should be carried out using an integral measurement method, and a stable reading lasting at least 30 s shall be obtained to represent the average value of the changes due to changes in the sound field.

6 Measurement procedure

6.1 Outlet noise measurement

Firstly, check and record the operating status of the measured HVAC system, especially if the individual exhaust outlets have been adjusted according to the designated flow rate. The data of flow rates should be recorded in the measurement report.

In order to reduce the turbulence effect of air flow from the outlets and to lower the measurement error, three microphones with windshields are placed on the tripods and located in one plane at an equal angle interval of β. The distance between each microphone and the edge of the measured exhaust outlet is 1 m. Position angle of the microphone, α, should be between 30° and 45° with inclination to the plane of the ceiling, as shown in Figure 3. For the case of outlets near the corners of the cabin, there is not enough space to place three microphones; one or two microphones of those should be adopted.



α = 30°- 45°, β = 120°, l = 1 m

Key

1 air flow
2 duct
3 outlet
4 ceiling
5 microphone
6 tripod

Figure 3 — Arrangement of the microphones

If there are more than two exhaust outlets in a large space, each outlet in the space should be measured.

In any case, measurements should not be made when the distance between the microphone and the boundary of the premises is less than 0,5 m.

6.2 Background noise measurement and outlet noise correction

The background noise measurement shall be made before or after the outlet noise measurement, when HVAC system is switched off.

The background noise shall be determined with the equivalent continuous sound pressure level over a period of approximately 30 s. The same microphone positions used for the outlet noise measurement shall be used. Calculate the energetic average of the background noise level in the three positions before correction of the outlet noise level.

Outlet noise correction should be made according to Table 1.

6.3 Reverberation time measurement

The reverberation time shall be measured by the interrupted sound source method, or alternatively the integrated impulse responses method, in accordance with ISO 3382-2. In order to measure the reverberation time, a sound source, i.e. a loudspeaker, shall be used to generate the sound within the room to monitor the decay of sound pressure level after the sound ceases.

The reverberation time of the space depends on the position of the source and the receiving microphone. The loudspeaker is usually placed in a corner of the space to be tested. The number and position of the microphones are the same as those of the exhaust noise measurements. The distance from any microphone-position to the nearest reflecting surface, including the floor, should be at least 1 m away. No microphone-position shall be too close to any source-position in order to avoid too strong influence from the direct sound.

The instruments used in the measurement of reverberation time should be capable of displaying and/or evaluating decay records/curves. Refer to ISO 3382-2.

Measure the background noise levels with the HVAC system off.

The loudspeaker shall be used as a sound source in the space, and a broadband or narrowband noise signal with a continuous spectrum, i.e. pink noise or white noise, shall be sent to the speaker.

With the speaker in operation, start the sound level meter. The measured noise level shall be 35 dB to 45 dB higher than the background noise level.

Turn off the loudspeaker and allow the sound to decay. Wait for the background noise to stabilize, and then stop the measurement.

The reverberation time measurement should be repeated at least five times to average multiple data measured at the microphone position to reduce measurement uncertainty due to statistical deviation.

When measuring reverberation time, it is preferable that there is no one in the space. If this is practically difficult, the operator of the measuring equipment can be present.

6.4 Result processing

6.4.1 Exhaust outlet noise level

If the HVAC system has only one exhaust outlet in the i^{th} cabin, its exhaust outlet noise level, L_i, is obtained by the energy averaging of noise measured by the used microphones, using Formula (1).

$$L_{\text{p,outlet}} = L_i = 10\log\left(\frac{1}{M}\sum_{j=1}^{M} 10^{\frac{L_j}{10}}\right) \quad (1)$$

where

M	is the number of microphones for noise measurement of the i^{th} outlet in a cabin;
L_j	is noise level of the j^{th} microphone, in dB;
$L_{\text{p,outlet}}$	is exhaust outlet noise level from all the exhaust outlets, in dB.

If more than two outlets are tested in a large cabin, the noise level of this cabin from all the exhaust outlets should be given by energy superimposition of noise levels from each of the outlets while the other outlets are switched off, using Formula (2):

$$L_{\text{p,outlet}} = 10\log\left(\sum_{i=1}^{N} 10^{\frac{L_i}{10}}\right) \quad (2)$$

where

N is the number of outlets to be tested in a cabin;

L_i is noise level of i^{th} outlet, in dB;

$L_{p,outlet}$ is exhaust outlet noise level from all the exhaust outlets, in dB.

6.4.2 Calculation of the cabin sound absorption

The cabin sound absorption is calculated based on the reverberation time and cabin parameters using the following Sabine's Formula (3):

$$T_{30} = \frac{0{,}161\ V}{-S\ln(1-\alpha)} \tag{3}$$

where

V is the volume of the cabin in m^3;

S is the total surface area of cabin in m^2;

α is the average absorption coefficient of cabin surfaces;

T_{30} is the time taken to decay 30 dB.

Another quantity representing the acoustic property of a cabin is room constant R, which is related to sound absorption α by Formula (4):

$$R = \frac{\alpha S}{1-\alpha} \tag{4}$$

Using the same assumption of small sound absorption, Formula (5) can be yielded:

$$R \approx 0{,}161V/(2*T_{30}) \tag{5}$$

Sound pressure level due to diffraction in a reverberant cabin $L_{p,rev}$ can be calculated by Formula (6):

$$L_{p,rev} = 10\log\left(\frac{4}{R}\right) \tag{6}$$

6.4.3 Determination of the vent noise levels

As the measured noise level of exhaust outlet is a summation of the vent noise with diffracted sound, the vent noise level is simply obtained by removing diffracted sound from the measured outlet noise, as shown in Formula (7):

$$L_{p,vent} = L_{p,outlet} - L_{p,rev} \tag{7}$$

where

L_{pvent} is vent noise level;

$L_{p,outlet}$ is the cabin noise level from exhaust outlet;

$L_{p,rev}$ is sound pressure level due to cabin reverberation.