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CHOICE OR CHANGE? REMARKS ON TEST ENVIRONMENTS FOR MACHINERY NOISE EMISSION MEASUREMENTS

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ABSTRACT
In standards for the determination of sound power levels and emission sound pressure levels it is presumed test environments will comply with certain requirements if a defined accuracy is aimed to. The requirements can comprise an approximation of a free field over a reflecting plane as in ISO 3744 and 3746 or in ISO 11 202 and 11 204 or it can be a more reverberant environment as in ISO 3747. A machine model with variable directivity, i.e. a van switched off with an additional sound source inside and differently adjusted windows has been measured in several rooms and its variations due to added or decreased absorption. With the tests given in the standards the compliance with the requirements was checked too. As a result of comparison with similar investigations some recommendations for users of the standards are being prepared.

1 - INTRODUCTION

The standard ISO 3740 gives "guidelines for the use of basic standards" and contains in an informative annex a flowchart showing the different decisions to find the appropriate test method. The three decisive questions are considering the possibility to move the source into a special environment, the background noise in the environment under discussion and if the environment approximates more or less a free field over a reflecting plane. The decisions are constrained by the recommendation to prefer a method of accuracy class 2, e.g. ISO 3744 or 9614. The latter depends on the use of instrumentation for intensity measurements. So an additional question seems obvious: can one adjust a given environment to the chosen requirements and is it economically feasible?

2 - TRIALS TO ADJUST THE TEST ENVIRONMENT

For measurements of sources with distinct directivity the test environment is especially critical. Local irregularities of the sound field are considered inappropriately by most of the test methods. Therefore a model machine has been used, consisting of a van (Peugeot 806) with a multiple loudspeaker system (Norsonic UVW) fed with white noise and radiating either through a single open window or through the vehicle walls completely shut. The open window version allows modeling of a wide range of the directivity index, see [1]. Levels of the sound pressure and the sound intensity have been measured always with an intensity probe (B&K 3548, pair of microphones 4181, spacer 12 mm) and analyzer (B&K 2144) in the third octave bands f_m = 200 to 5000 Hz in three different rooms of a laboratory building. These rooms were changed by means of an additional reflector (lamin. board 20 mm, 7 ×3 m) or additional absorbent lining (10 cm PU foam, α>0.9 above f_m = 500 Hz), see table 1.

room	l × b × h [m]	volume [m^3]	Area lined [m^2]	$K_{2,1k}$ dB
hemianechoic	14 × 9 × 6	760	wall, ceiling	"0"
hemianech. & reflector				
hall	22,5 × 18,5 × 10	4160	1 wall=34	*2?* (2,3)
doorway	8 × 5 × 4	160	3 walls=86	2,5 (7)

Table 1: Environments applied.

Besides the advantageous movability of an automobile used as a model machine there is a disadvantage too. The spectra of the different versions of radiation are differing remarkably as shown for octave bands in table 2. The high frequencies of the generated white noise are insulated very effectively due to the current design of a car body completely closed and compared to the radiation through an open side window.

Version / f_m [Hz]	250	500	1000	2000	4000
F1, omnidirectional	71	65	62	61	61
F2, directional	75	73	74	77	73

Table 2: Octave band spectra ($L_{Woctave}$) of the model machine for omnidirectional and directional radiation in dB.

Statutory provisions require the use of A-weighted noise emission quantities. To compare the effects of the proposed changes of the environment for both the radiation versions it is necessary to use an appropriate and representative spectrum for an uniform calculation of A-weighted levels. Table 3 shows such "industry" octave-band spectrum (from [1]) which is widely similar to the "M"- spectrum for testing hearing protectors according prEN 352.

Spektrum / fm [Hz]	250	500	1000	2000	4000
"Industry"	-11	-6	-5	-6	-10

Table 3: A-weighted relative octave-band spectrum in dB for uniform calculation of real noise A-levels.

The deviations of the different third octave - or octave- band levels from the levels determined in the hemianechoic room under ideal conditions were applied to the above spectrum to get the deviations of A-levels of real noise sources.
Environmental corrections K_2 were determined mainly by measurements at a reference sound source (RSS B&K 4204) on four different measuring surfaces according to table 4.

	Form	area [m^2]	L_S dB	n meas. points acc. ISO	
				3744	9614
Q 1	parallelepiped, 6,5 × 3,5 × 2,7 m	80	19	28	94
Q 2	parallelepiped, 2 × 2 × 2 m	20	13	9	./.
H 1	hemisphere, r=3,6 m	80	19	20	./.
H 2	hemisphere, r=2,0 m	25	14	20	./.

Table 4: Measurement surfaces.

The sound power levels of the two radiation versions have been determined by measurements of sound pressure levels on 28 measuring points, intensity levels on 94 points on a parallelepiped 1 m distant from the van surface, see table 4. The 22 points 1.36 m above the floor as part of the big number on the parallelepiped Q1 have been used for the determination of emission sound pressure levels according to the different standards. Irregularities of the sound field on the measuring surface have been investigated by positioning the microphone probe in five 2 cm steps to both sides of the original measuring point near the open van window.

3 - RESULTS

Results shown here are concentrating on comparisons between different versions of the doorway and the hemianechoic room as a reference where the true values have been determined. Differences ΔL of sound power levels according to ISO 3744 in octave bands are displayed in fig. 1. Firstly there is the evident change of the deviation from the true value related to the lining with additional absorption. This is confirmed by fig. 2 containing the nearly similar change of the average environmental correction K_2 .

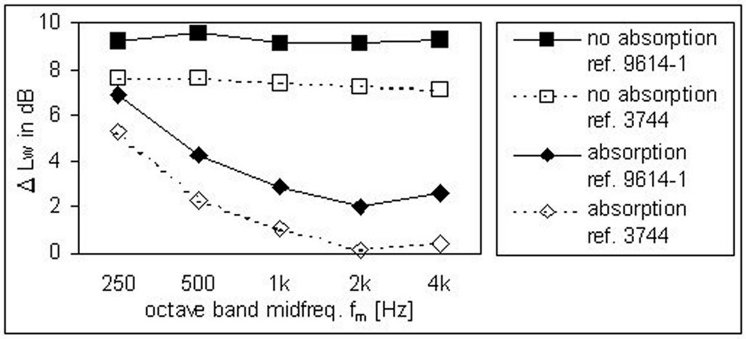

Figure 1: Deviations ΔL of octave band sound power levels from the true value determined acc. to ISO 9614-1 or ISO 3744 for two versions of the same room.

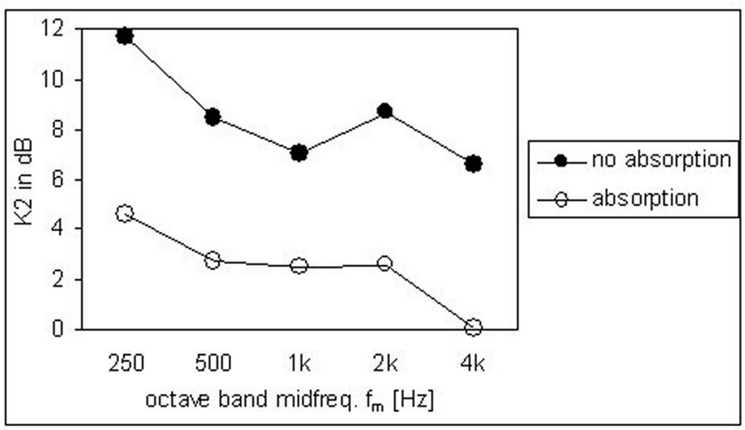

Figure 2: Environmental correction K_2 in octave bands for the room versions of fig. 1.

Secondly fig. 1 encourages the assumption that the difference between the chosen reference is a result of the angle error occurring with measurements according to ISO 3744, which have been carried out with the pressure values taken at the same 94 measuring points of the intensity probe, see [2]. Applying the octave band deviations to the spectrum of table 3 leads to a difference of ΔL_A=3.5 dB without correction K_2 and 1.0 dB with it (see fig. 2) from the true value. That is according to the required accuracy and was achieved with moderate costs.

Additional absorption seems less efficient if used for the determination of emission sound pressure levels either according to ISO 11204 or 11205. Fig. 3 and Fig. 4 show the deviations from the true value, i.e. the sound pressure level determined in the heminanechoic room, as a function of the freefield directivity index DI related to all 94 measuring points; the local environmental correction K_3 has been calculated for 22 points around the model machine and the corresponding mean. K_3 has been set to 7 in case of exceeding this limit.

4 - DISCUSSION

Changing the absorption can be an appropriate means to adjust given rooms to the requirements of the standards and to achieve the necessary accuracy of the determination of sound power levels and emission sound pressure levels as well. Always the alternatives should be weighed: On one hand costs for the change, either increase or decrease of absorption, on the other side either higher efforts and costs as increased number of measuring points on measuring surfaces less distant than the proposed one meter or a more expensive equipment in case of the application of ISO 9614 and 11205.

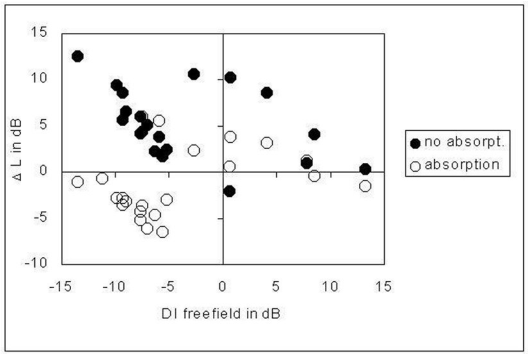

Figure 3: Deviations ΔL of emission sound pressure levels acc. ISO 11204 (1kHz 1/3 octave) from the true value on 22 points around a directional source in two versions of the same room.

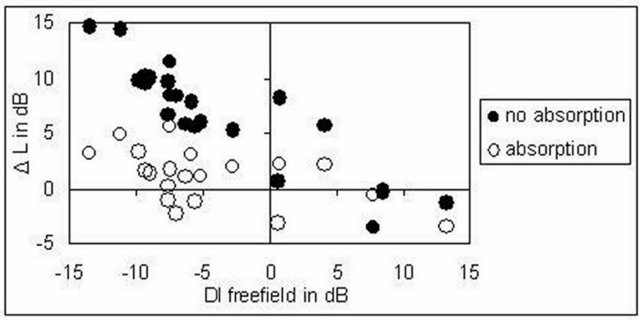

Figure 4: Deviations ΔL of emission sound pressure levels acc. ISO 11205 (1kHz 1/3 octave) from the true value on 22 points around a directional source in two versions of the same room.

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