inter-noise 83

NOISE CONTROL IN A VERY LARGE HALL OF A SHIPYARD

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INTRODUCTION

The advantages of working in an indoor slipway of a shipyard, compared to a normal outdoor slipway, are mainly thermal of character, namely working under frostproof conditions, no wind, no rain, no snow, no fog and so on.
Acoustically spoken there are besides advantages, such as less noise transmission to the environment, also some disadvantages. The main disadvantage is the potentially higher noise level for people working in the indoor slipway, in consequence of reflections against walls and ceiling.

NECESSITY OF NOISE CONTROL

High sound levels are practically unavoidable in a slipway, in any case at short distances of the sound sources.
In the open-air the sound level decreases at a greater distance of the sound source according to fixed rules so that the sound levels of different sources together will be restricted when one stays at a certain distance from the sound sources.
In a room the sound levels become in the entire room (much) higher due to reflections.
This has negative effects:
- the possibility of hearing damage will grow, as the number of people who will be exposed to high sound levels, increases
- the speech intelligibility will be diminished
  Bad communication has in any case an uneconomic influence. It can therefore create dangerous situations and hamper social relations.
- the workingperformance will in general decrease caused by psychological and social impediment
  Besides, in a noisy environment with many noise reflections, one

cannot clearly hear where the noise is coming from, which may be dangerous and in general will be felt as uncomfortable.

NOISE SOURCES

The noise sources during the construction of a ship or the section of a ship are mainly mechanical of character; the noise originates mostly from using hand held tools.
Some noise levels at 1 m distance are given in table I.

Table I. Noise sources

Source	L_{eq} in dB(A)	Source	L_{eq} in dB(A)
oxy-acetylene cutting	84	welding	76
grinding	99	hammering	103
arc gonging	109	sand blasting	110
clipping	111	hammering on wedges	106
redressing	108	spray-painting equipment	102*
*peak level			

NOISE REDUCTION

Noise can be reduced both in the emission and in the transmission. Reduction of the noise emission may be achieved by modification of the working procedure, so there will arise less (structure-borne) noise or the efficiency of radiation will be less.
If it is impossible to reduce the emission in practice, the possibilities in the transmission have to be checked. Examples are barriers, wrapping, enclosures, absorption, etcetera.
An integrated sound absorbing system of the walls and the ceiling from a very large hall of a shipyard (260 x 92 x 55 m^3) near Rotterdam will be dealt with in this paper, see fig. 1.

ABSORPTION

Normally to realize sufficient sound absorption in a room there will be absorption added to the walls, and a sound absorbing ceiling or baffles.
In this case with respect to the large size of the surfaces, the absorption could be integrated as a system in the wall- and the roof-construction. The construction had not only to be sound absorbing and sound insulating, but also thermal insulating. Chosen is for the construction of wall and roof as shown in figures 2 and 3. Measurements in the reverberation room of our laboratory, in conformity with ISO/R 354-1963, gave the absorption coefficient as a function of frequency, see figures 2 and 3.

REVERBERATION, THEORY AND PRACTICE

Most reverberation theories have been based on the assumption that a room has one reverberation time. That assumption however proves for large halls (> ca. 500 m^3) not to be correct. If one measures the reverberation time in a large hall, one may find for all relevant combinations of source and microphone position different results. The measured reverberation times form in general a Gauss distribution having a mean value of the reverberation time for the hall and a standard deviation which is for large halls as discussed larger than 10%. So one may not speak of the reverberation time of a larger hall, but one determines a mean reverberation time T_m.
The theoretical deduction of the reverberation time formula of Sabine ($T_S = \frac{1}{6}\frac{V}{A}$) presupposes a diffuse sound field, i.e. homogeneous and isotropic everywhere in the room and that independant of the time. Of course in practice this will never be the case: be it only for the fact that most of the sound absorption is to be found at the room boundaries.
It can be shown [1], that if in the mean the incident sound intensity at the absorbing boundaries is higher than would agree with the mean sound energy density taken over the whole room, a shorter reverberation time than according to the Sabine formula may be expected.
If one analyses the formula of Eyring $\left(T_E = \frac{V}{-6S \ln(1-\Sigma \alpha_i S_i/S)}\right)$ one must conclude that in it implicitly is assumed, that the incident sound intensity is higher than corresponds with the mean energy density. As sound in larger halls travels longer before colliding with a boundary ($\frac{4V}{S}$, the mean free path will be longer), this effect will be more important the larger the hall.
In tabel II one finds T_S, T_E and T_m as determined for the hall of the shipyard ($\frac{4V}{S} \approx 61$ m). T_S and T_E have been corrected for the air dissipation.

Table II. Reverberation times (s) as a function of frequency (Hz).

	125	250	500	1000	2000	4000
T_S	6,7	6,2	5,8	5,7	5,4	4,2
T_E	5,4	4,8	4,5	4,7	4,3	3,5
T_m	6,8	5,8	5,1	4,8	4,4	3,4

For the lower frequencies the sound field will as is well known, in general be more diffuse, so the measurements will be more Sabine-like, for the higher frequencies (≥ 1000 Hz) the Eyring formula is more realistic.

DECREASE WITH DISTANCE

Figure 4 shows the decrease of the sound level with distance as calculated and measured. Differences of more than 10 dB at larger distances can be found compared to a hall without absorption.

CONCLUSION

By improving the sound absorption in a very large indoor slipway of a shipyard there are no acoustical disadvantages of these indoor activities, but only advantages.

[1] Peutz, V.M.A.; Nouvel examen des théories de réverberation. Revue d'Acoustique 14 (1981) p. 99

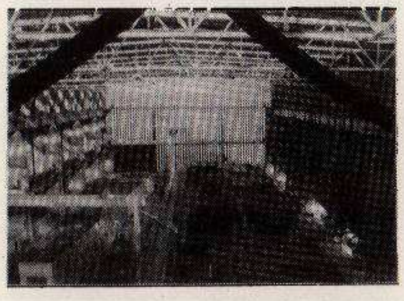
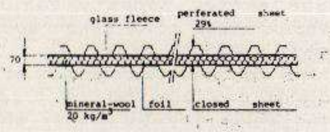
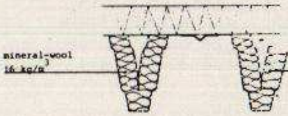


Fig. 1. Indoor slipway near Rotterdam



frequency	125	250	500	1000	2000	4000	Hz
a_s	0.47	0.58	0.58	0.63	0.63	0.65	

Fig. 2. Integrated system of the wall.
Absorption as a function of frequency



frequency	125	250	500	1000	2000	4000	Hz
a_s	0.88	0.87	0.95	0.77	0.83	0.74	

Fig. 3. Integrated system of the roof.
Absorption as a function of frequency.

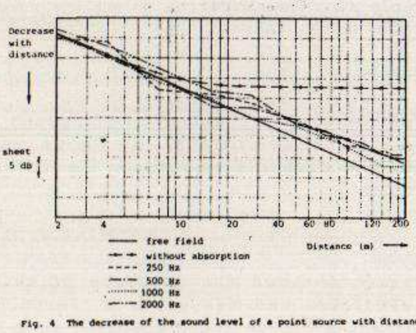


Fig. 4 The decrease of the sound level of a point source with distance.