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TRANSFER OF STRUCTUREBORNE SOUND TO SHIP'S CABINS

M.J.A.M. de Regt

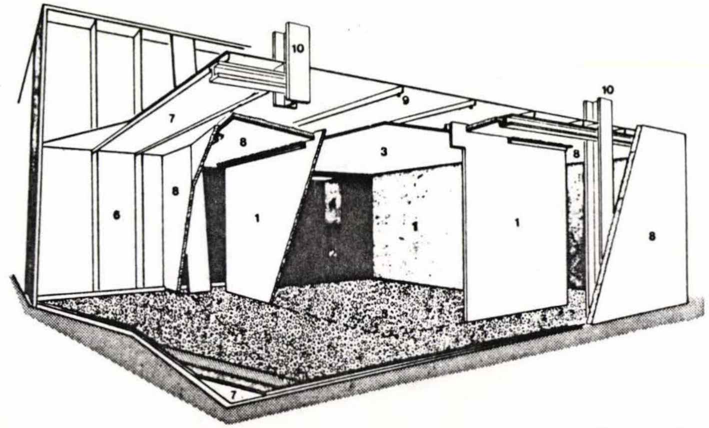
TPD, Institute of Applied Physics,
Postbus 155, 2600 AD Delft
The Netherlands

SUMMARY

In the laboratory the transfer of structureborne sound from a ship-like steel structure to cabin bulkheads has been investigated for three types of bulkhead material: chipboard, plastic faced calcium silicate and steel plates sandwiching a rock wool core. The most relevant results of the investigations are discussed: the influence of the applied materials for bulkheads and ceiling on the resulting sound pressure level in the cabin, the effect of the installation of a floating floor and the effect of the presence of a porthole. Estimates are given for the attainable insertion losses of floating floors on board ships.

INTRODUCTION

For the reliable prediction of noise spectra in accommodation spaces on board ships quantitative knowledge is required about the structureborne sound path between source and receiver. A part of this sound path, the transfer of sound from the steel structure in way of the cabin, is accessible for experimental investigations in the laboratory. Experiments were carried out on cabins built up between two steel decks welded to the outside of a ship-like watertank (fig. 1).



1. cabin bulkheads
2. lining
3. ceiling
4. port hole
5. floating floor
6. water tank
7. decks
8. sound insulating construction
9. rubber mounts
10. pillars free from decks

Fig.1:The cabin installed on top of the floating floor in the laboratory facility

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Three different types of bulkhead materials were used: chipboard, plastic faced calcium silicate and steel plate sandwich panels with rockwool core (see ref. [1]-[3]). For the first and last mentioned materials a cabin on board a ship has been investigated as well (ref. [4] and [5]). The research was sponsored by the Netherlands Maritime Institute. In this paper the most relevant data are presented. To describe the "overall" effectiveness of the applied acoustical measures the expression (L_p-L_v) is used, being the relation between the resulting sound pressure levels in the cabin (L_p in dB re 20 μPa) and the velocity levels of the steel deck (L_v in dB re 50 nm/s). [x]
To facilitate comparisons the reverberation time of the investigated cabins was normalized to 0.5 s in the relevant frequency range.

CABINS INSTALLED ON BARE STEEL DECK

In the laboratory

The cabins were installed on a 6 mm thick bare steel deck without any further connection to the steel structure. This deck was excited at a position on the "hull" underneath the cabin (exciter 1 m below the deck). From the measurements it appears that:

1. the L_v's of the bulkheads are in general caused by transfer of structureborne sound from the steel deck, not by airborne noise radiated by hull or deckhead
2. the type of coupling between the steel deck and the bulkheads as used in the laboratory (U-profile with or without felt inlay) causes the L_v's of the bulkheads to be 5 to 10 dB lower than the L_v's of the steel deck
3. the sound radiation by the steel deck determines the L_p in the cabin over the frequency range 100 Hz - 2500 Hz. There are indications that this is also valid for the 63 Hz-octave band. Decoupling of the steel plate sandwich panels from the steel deck by means of a rubber strip lowered the L_v's of the bulkheads considerably (5 - 15 dB) without any significant decrease of the L_p !
4. in accordance with 3. the (L_p-L_v)'s measured for the three types of bulkhead material show only small differences except for the 63 Hz-octave band. In this octave band the modal density is very small in the steel basin structure as well as in the cabin's space (lowest natural frequency at 70 Hz): variation in room dimensions and microphone positions for the various experiments may probably cause the scatter presented in figure 2.

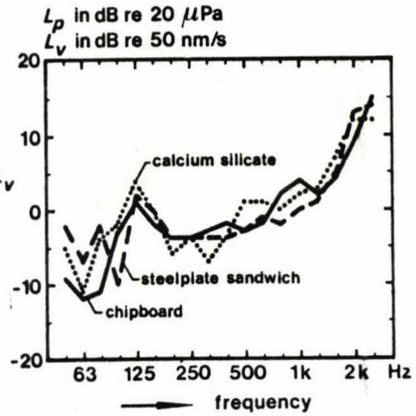

Fig. 2: (L_p-L_v)'s measured in laboratory for cabins built from different materials; cabins on bare steel deck

x) Note: the reference level deviates from the present standardized level of 1 nm/s, but allows a convenient connection with the referred literature.

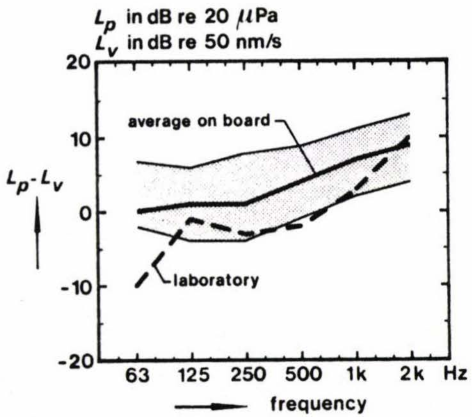

Fig. 3: (L_p-L_v)'s measured for six chipboard cabins without acoustical measures on board six different ships. The average and the extreme values are given. Moreover the (L_p-L_v) for a chipboard cabin in laboratory is presented.

On board ships

In figure 3 the (L_p-L_v) which was found in the laboratory for the chipboard cabin is compared with the (L_p-L_v)'s measured for six chipboard cabins on board six different ships. Because the L_p in the cabin in the laboratory could be explained from the sound radiation of the steel deck, it is clear that this will form the lower boundary of the (L_p-L_v)'s measured on board. Higher (L_p-L_v)'s may occur on board because:

1. a levelling layer on top of the steel deck and/or an increased thickness of the steel deck leads to a more efficient radiation of the steel deck in the frequency range of interest
2. another type of coupling between steel deck and cabin bulkheads (for instance butyl compound in U-profile) or other connections to the steel structure may lead to higher L_v's of the bulkheads resulting in a higher contribution of the bulkheads to the L_p in the cabin
3. in furnished cabins on board other sound radiating surfaces, such as berths, wardrobes, etc. may be of influence.

CABINS INSTALLED ON FLOATING FLOOR

In the laboratory

In general floating floors are applied to lower the sound radiation of the floor construction and to reduce the L_v of the cabin boundaries installed on top of the floating floor. For the experiments carried out in the laboratory a floating floor was used composed of an underlayer of 25 mm glass fibre and a toplayer of asphalt combined with latex cement (about 70 kg/m^2). The same floating floor was used for the chipboard and the steel plate sandwich cabin. The floor was renewed for the experiments on the calcium silicate cabin. The insertion loss with respect to the L_v of the floating floor, defined as the difference between the L_v of the steel deck without floating floor and the L_v of the top layer of the floating floor, measured with the same excitation force applied to the "hull" below the cabin, is given in figure 4.

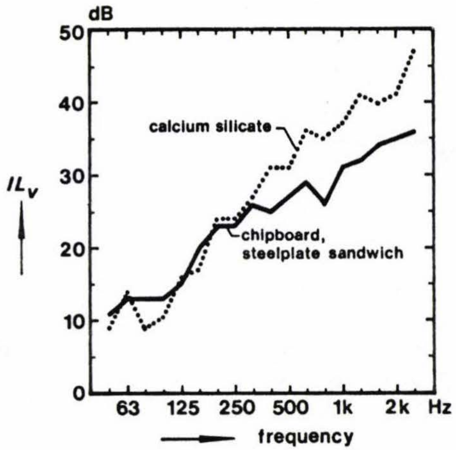

Fig. 4: Insertion losses with respect to the velocity levels of the floating floors used during the experiments in laboratory: (toplayer about 70 kg/m^2; resilient layer: 25 mm glass fibre)

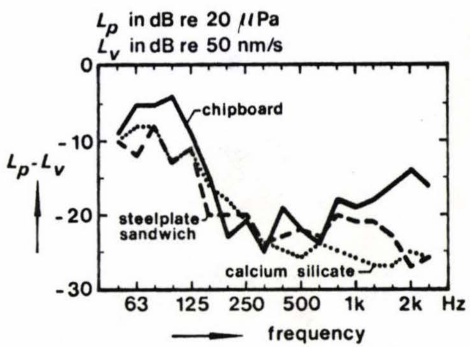

Fig. 5: (L_p-L_v)'s measured in laboratory for cabins built up from different materials; cabins installed on top of floating floor (see Fig. 4)

The main results of the experiments in the laboratory are:

1. the L_v's of the bulkheads are caused by transfer of structureborne sound from the floating floor to the bulkheads. This transmission path is apparently more efficient (ΔL_v's $\simeq$ 0 - 5 dB) than in the case of the bare steel deck (ΔL_v's $\simeq$ 5-10 dB).
2. the attainable level difference between the steel deck and the lining is in the 500 - 2000 Hz octave band limited to about 40 dB by the airborne noise radiated by the hull, even if a 50 mm thick layer of glass fibre is attached to the hull
3. connections of the cabin structure to the deckhead, if realised by means of soft rubber mountings, do not severely affect the attainable gain
4. in the frequency range below 1000 Hz the L_p in the cabin is mainly caused by the sound radiation of the floating floor; for the chipboard cabin, however, the contribution of the bulkheads in the lowest octave bands is important
5. the (L_p-L_v) for the chipboard cabin shows in the 63 Hz and 125 Hz octave bands 4 to 5 dB higher values than for the other cabins (see fig. 5). Above the 500 Hz-octave band the results diverge: for the chipboard cabin the airborne sound excitation of lining and ceiling becomes important; for the calcium silicate cabin yields that the floating floor showed an apparently higher IL_v in this frequency range due to a changed edge connection.

On board ships

For a chipboard cabin and for a cabin built up with steel plate sandwich panels the (L_p-L_v) measured in the laboratory and on board are given in the figures 6 and 7. The data have been corrected for differences in IL_v of the floating floors applied. The (L_p-L_v)'s as measured on board are in agreement with the data obtained by the laboratory experiments. Only in the 63 Hz octave band very large differences occur for the cabin with steel plate sandwich panels; however, the bulkheads on board showed in this octave band up to 15 dB higher L_v's than the floating floor, probably caused by structureborne short circuiting.

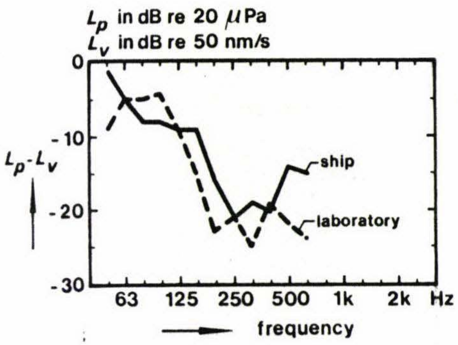

Fig. 6: (L_p-L_v)'s measured for a chipboard cabin installed on top of a floating floor on board and in the laboratory. The results were corrected for differences in the floating floors applied

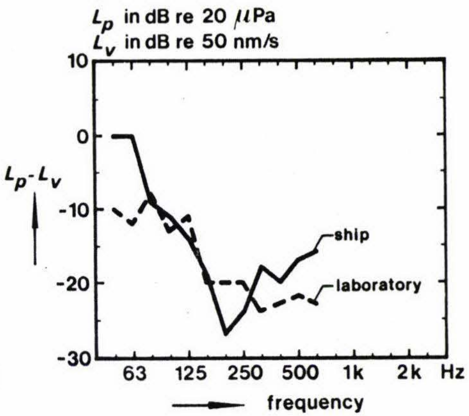

Fig. 7: (L_p-L_v)'s measured for a cabin constructed of steel plate panels installed on top of a floating floor on board and in the laboratory. The results were corrected for differences in the floating floors applied

INFLUENCE OF TYPE OF CEILING AND PORTHOLE

For the calcium silicate cabin two types of ceiling structures were examined. The "heavy" one consisted of 11 mm thick plastic faced calcium silicate; the light weight ceiling was composed of .7 mm thick profiled steel plates. The measurement results show that for cabins installed on top of a floating floor a lightweight ceiling limits the (L_p-L_v) considerably (see fig. 8).
From the measurements in cabins provided with portholes, two in the laboratory and two on board, it can be derived to what extent the (L_p-L_v) in a cabin is restricted by the presence of a porthole. In figure 8 the average values are given.

ATTAINABLE (L_p-L_v) AND IL_p

An engineering estimate of the influence of different sound reducing measures on the (L_p-L_v) in a cabin on board a ship is given in fig. 9. To obtain the data given for "heavy ceiling" it is necessary that the cabins are installed on top of a floating floor without any rigid connection to the steel structure and that a 50 mm thick layer of sound absorbing material is applied to hull and deckhead. In general the influence of a floating floor or a ceiling structure depends of course heavily on the type used. The curves may give an indication based on measurements in the laboratory and on board. The influence of a porthole on the (L_p-L_v) is rather disastrous if at high frequencies a high insertion loss is needed. However, in cabins in the propeller region and above slow-speed diesel engines it is possible that the presence of a porthole hardly affects the NR-number of the spectrum.
The insertion loss with respect to the sound pressure levels in the cabin can be derived from figure 9 as being $\Delta(L_p-L_v)$. However it should be taken into account that the L_v of the steel deck is decreased by about 8 dB in the 63 Hz-octave band if on top of it a floating floor as was used for the experiments is installed. Thus an IL_p of 6 dB in the 63 Hz-octave band rising to more than 20 dB in the frequency range above the 250 Hz-octave band is attainable; with a porthole installed the IL_p at higher frequencies is limited to about 15 dB.

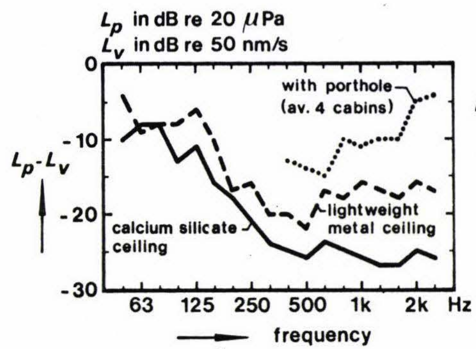

Fig. 8: Influence of the type of ceiling, measured for the calcium silicate cabin, and of a porthole on the (L_p-L_v) for cabins installed on top of a heavy floating floor

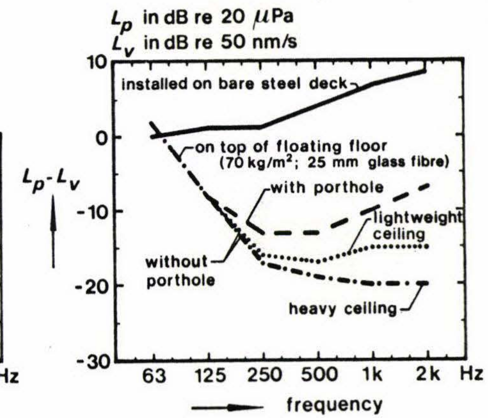

Fig. 9: Engineering estimate of the influence of the different sound reducing measures on the resulting (L_p-L_v)

EVALUATION

Experiments in the laboratory on complete cabins give insight in the transfer of sound from the ship's steel structure to a cabin. The results are consistent with findings on board ships. The relative influence of different sound reducing measures on the cabin's sound level can be reliably assessed. Accurate prediction is feasible.

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