# MEASUREMENT OF THE EFFECT OF FITTINGS ON LOW-FREQUENCY SOUND IN A SCALE MODEL WORKROOM

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## 1. INTRODUCTION

The spatial variation of low-frequency sound was measured in a scale model workroom when empty, fitted with large fittings, and fitted with small fittings. Although the effects of fittings on high-frequency sound have been studied extensively [1,2], its effects on low-frequency sound have not generally been investigated. The results of this study will be used to determine the accuracy of prediction models to account for fittings in active noise control (ANC) prediction. Previous prediction work with ANC has not taken into account the effect of fittings [3,4].

## 2. EXPERIMENTAL SETUP

The scale model room was set up at 1/8th scale to model a rectangular workroom with dimensions of 30mFS x 15mFS x 7.5mFS (FS = Full Scale equivalent value). The floor was unpainted concrete. The walls were made of 10mm plywood, varnished on the inner surface while the roof consisted of 3mm plywood, varnished on the outer surface. The walls and roof were supported by a metal frame.

The large fittings were 2mFS cubes constructed of 6mm plywood, varnished on the outside. Ten cubes were evenly distributed around the room, leaving an area of about 8mFS around the source unobstructed. The small fittings were solid wood blocks, with dimensions of 1mFS x 0.65mFS x 0.65mFS. Forty blocks were evenly distributed around the room, also leaving an area of about 8mFS around the source unobstructed.

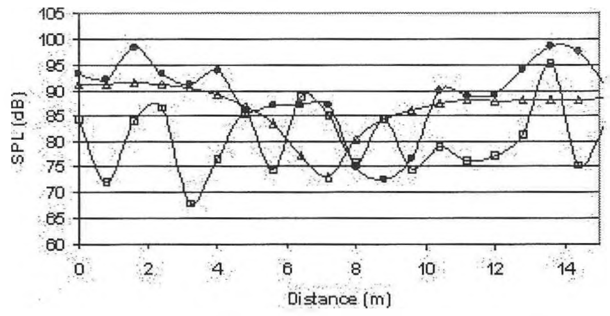
A single 100mm loudspeaker was used as a source in the scale model tests. It was placed in a 120mm x 120mm x 200mm enclosure, with the speaker set in 80mm from the top face of the enclosure. For measurements of the steady-state level, the speaker was positioned facing one corner of the scale model, in an effort to obtain the maximum excitation of the modal response in the scale model.

Sound pressure level measurements were made along a line down the length of the scale model room. Also, two lines along the width of the room were measured, one close to the source, and one far from the source. To ensure that the line measured was not along a nodal line, the lines were carefully chosen and measurements were made along lines with many antinodes in the empty room. This resulted in choosing slightly different lines for each of the frequencies measured. The receiver microphone was placed at a height of 1.6mFS for all measurements.

## 3. RESULTS

The scale model workroom was tested using pure tones at 31.5, 63, and 125HzFS under three different conditions – empty, fitted with large fittings and fitted with small fittings. The sound pressure level versus distance away from the source was compared at each of the three frequencies measured, for the three different room conditions. Fig. 1 shows an example of the sound pressure level variation with distance away from the source measured along the width of the scale model room.

As shown in Fig. 1, the addition of fittings caused the variation in low-frequency sound pressure level in the room to change significantly from the empty workroom. In order to more easily and directly compare the differences between each of the room conditions, a linear regression line was fitted to the data and the residual standard deviation ($S_{y|x}$) was calculated. These values are listed in Tables 1, 2 and 3 corresponding to measurements made along the length of the workroom, the width close to the source and the width far from the source, respectively. The reverberation times (RT) were also measured for the three different room cases; their values are listed in Table 4.




● - Empty △ - Small Fittings □ - Large Fittings

Fig. 1. SPL versus distance measured along the width of the scale model room close to the source, at 31.5HzFS.

Table 1. Residual standard deviation (in decibels) of the sound pressure level at 31.5HzFS, 63HzFS and 125HzFS, measured along the length of the workroom.

| | 31.5HzFS | 63HzFS | 125HzFS |
|---|---|---|---|
| Empty | 7.0 | 7.3 | 7.8 |
| S Fitted | 3.5 | 7.1 | 5.7 |
| L Fitted | 7.7 | 7.1 | 5.1 |

Table 2. Residual standard deviation (in decibels) of the sound pressure level at 31.5HzFS, 63HzFS and 125HzFS, measured along the width of the workroom close to the source.

| | 31.5HzFS | 63HzFS | 125HzFS |
|---|---|---|---|
| Empty | 7.4 | 6.1 | 6.8 |
| S Fitted | 4.9 | 3.3 | 5.8 |
| L Fitted | 6.7 | 8.5 | 5.7 |

Table 3. Residual standard deviation (in decibels) of the sound pressure level at 31.5HzFS, 63HzFS and 125HzFS, measured along the length of the workroom far from the source.

| | 31.5HzFS | 63HzFS | 125HzFS |
|---|---|---|---|
| Empty | 8.3 | 5.1 | 3.4 |
| S Fitted | 7.6 | 6.9 | 5.3 |
| L Fitted | 6.4 | 4.8 | 4.5 |

Table 4. Reverberation times (in seconds, full scale) measured at 31.5HzFS, 63HzFS and 125HzFS, for the three different room cases.

| | 31.5HzFS | 63HzFS | 125HzFS |
|---|---|---|---|
| Empty | 6.3 | 7.6 | 7.2 |
| S Fitted | 6.1 | 6.6 | 6.3 |
| L Fitted | 3.5 | 5.0 | 5.7 |

## 4. DISCUSSION

Along the length of the scale model workroom, the most spatial variation occurs when the room is empty at 125HzFS, with a $S_{y|x}$ of 7.8dB. The addition of small fittings generally decreased the spatial variation compared to the empty room, but it was highest at 63HzFS. At 31.5HzFS, the small fittings decreased the $S_{y|x}$ to 3.5dB. With the large fittings, at 31.5HzFS, the $S_{y|x}$ increased slightly by 0.7dB, while at 125HzFS it was decreased by 2.7dB.

Close to the source and along the width of the workroom, spatial variation was highest at 31.5HzFS when empty. Small fittings decreased the $S_{y|x}$ by 2.5dB at 31.5Hz and 2.8dB at 63Hz. Large fittings decreased the $S_{y|x}$ slightly at 31.5 and 125HzFS, but increased it by 2.4dB at 63HzFS.

In the empty room, along its width and far from the source, the $S_{y|x}$ was highest at 31.5HzFS with a value of 8.3dB. At 125HzFS in the empty room, the $S_{y|x}$ was quite low, at 3.4dB. The addition of fittings decreased the $S_{y|x}$ at 31.5HzFS by 0.7dB and 1.9dB for the small and large fittings, respectively. At 63 and 125HzFS the fittings tended to increase the $S_{y|x}$.

Overall, the small fittings tend to smooth out the spatial variation in sound pressure level, but at distances far from the source, large fittings lowered the variation more than the small fittings.

The fittings decreased the overall RT in the room compared to the empty room; the large fittings more than the small fittings. At 31.5HzFS, the small fittings did not decrease the RT significantly compared to the empty room, but at 63 and 125HzFS it decreased the RT by about 1s. The large fittings decreased the RT considerably – by over 2.5s at 31.5 and 63HzFS and by 1.5s at 125HzFS. The monotonic decrease in RT due to the introduction of fittings (from empty to small fittings to larger) compared to the empty room does not tend to follow changes seen in the $S_{y|x}$ for the different room conditions.

## 5. CONCLUSIONS

The spatial variation in the sound pressure level in a scale model workroom is changed significantly with the addition of fittings in the room. Overall, small fittings tended to decrease the amount of variation in sound pressure level in the room. Small fittings tended to decrease the variation in sound pressure level more than large fittings, close to the source, while far from the source large fittings decreased the variation more than small fittings. The RT does not correlate with the amount of variation of the sound pressure level measured in the room.

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