

inter.noise 2000
The 29th International Congress and Exhibition on Noise Control Engineering
27-30 August 2000, Nice, FRANCE

I-INCE Classification: 5.3

AN EXACT METHOD TO DETERMINE THE INFLUENCE OF NOISE CONTROL MEASURES IN WORKPLACES

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Keywords:
OCCUPATIONAL NOISE, SOUND PROPAGATION, ROOM ACOUSTICS, MEASUREMENT METHODS

ABSTRACT
In a Finnish research project the effects of accomplished noise control measures were to be determined in 10 existing workplaces. One of the primary objects was to develop a simple and exact measurement method that could be used to verify the influence of typical noise control measures. The method should take into account fittings, screens and other obstacles that have influence on the sound propagation. In the new method sound pressure levels are measured at work stations using an omnidirectional loudspeaker in carefully selected locations. The workshop's inherent noise can not be utilized as the test sound because the noise level varies too much. Measurements are done before and after the noise control measures in the same measurement positions. The influence of the noise control measure is described in decibels as the in situ sound attenuation or insertion loss. The application of the method in one workplace will be presented as an example. The new method was compared to existing methods: the reverberation time method and the spatial sound distribution method according to ISO/CD 14257. The reverberation time method produced a rough underestimated approximation of the influence of noise control measures. ISO/CD 14257 produced DL2 and DLf parameters but not intuitive values of the influence in sound pressure levels. The new method produced the influence directly in decibels at work stations, which is the information that the customers are interested in. This method has also been used to test the reliability of the room acoustical computer model of a workplace. The test is especially recommended in large, flat and fitted halls.

1 - INTRODUCTION

In a Finnish research project, the effect of different noise control measures needed to be determined in 10 operating workplaces. One of the primary objects was to develop a simple and exact measurement method that could be used to verify the influence of typical noise control measures (NCMs). The method should take into account fittings, screens and other obstacles that have an influence on sound propagation. The new method was compared to existing methods: the reverberation time method and the spatial sound distribution method according to ISO/CD 14257. The application of the compared methods in one workplace is presented as an example, where 100 % of the ceiling area was covered with 30 mm mineral wool.

2 - MEASUREMENT METHODS

All the measurements were done before the NCMs and repeated afterwards when the NCMs had been carried out. The measurement situations were arranged so that the background noise level was at least 6 dB lower than the test sound and the measurement points and conditions were the same before and after the NCMs. All measurements were done in $125-4000$ Hz octave bands.
An omnidirectional sound source (B&K 4296), a power amplifier (QSC 1300 W USA) and a pink noise signal source (Behringer DSP 8000) were used as the sound source in all measurements. The sound power level of the sound source was determined in a reverberation room according to ISO 3741.

Sound pressure levels (SPL) in the workplace were measured using a precision sound level meter (B&K 2260A) equipped with a 1/2" microphone (B&K 4189). A digital tape recorder (Tascam DA-P1) was used to record pistol shots in the reverberation time measurements. The shots were recorded via the sound level meter and the recordings were analyzed with a real time analyzer (B&K 2133) using Schroeder's backward integration.

3 - THREE METHODS TO DETERMINE THE EFFECT OF NCMS

In the workplace, the following three methods were used to determine the effect of the NCMs.

3.1 - Reverberation time method

The reverberation time was measured using a pistol shot as the sound source. Decays were recorded in 4 locations and analyzed afterwards.

3.2 - Spatial sound distribution method (ISO/CD 14257)

The omnidirectional sound source was located in the middle of the workplace at a height of 1.5 m (Fig. 1, S2). The SPLs were measured in the line of sight of the sound source at fixed distances 1, 2,..., 9, 10, 12, 14,..., 20, 24,..., 48, 56 m from the source. The acoustical parameters DL_2 and DL_f were calculated as described in the standard. DL_2 is determined as the spatial decay of SPL per distance doubling, and DL_f as the excess of SPL with respect to a reference spatial sound distribution curve which would occur in a free field without any reflecting surfaces or scattering bodies.

3.3 - Insertion loss method (new method)

The omnidirectional sound source was placed in carefully selected location(s). Usually position(s) close to real noise sources (machines) were used. The SPLs were measured at selected measurement points, which were usually close to work stations. The source location (S1) and the measurement points (1...9) in the workplace are presented in Fig. 1.

The sound attenuation dL_i was calculated by subtracting the measured SPL $L_{p,i}$ at the measurement point i from the sound power level of the sound source L_w. The insertion loss was calculated from the sound attenuation results by subtracting the dL_i values before the NCMs from the values after the NCMs.

A similar calculation procedure as that above was applied to the spatial sound distribution results. The distance ranges of 4...12 m, 13...24 m and 25...50 m were selected. The measured SPLs within selected ranges were averaged and dL was calculated by subtracting the average sound pressure level $L_{p,range}$ within the range from the sound power level L_w of the sound source. The insertion loss was calculated by subtracting the dL values before the NCMs from the values after the NCMs.

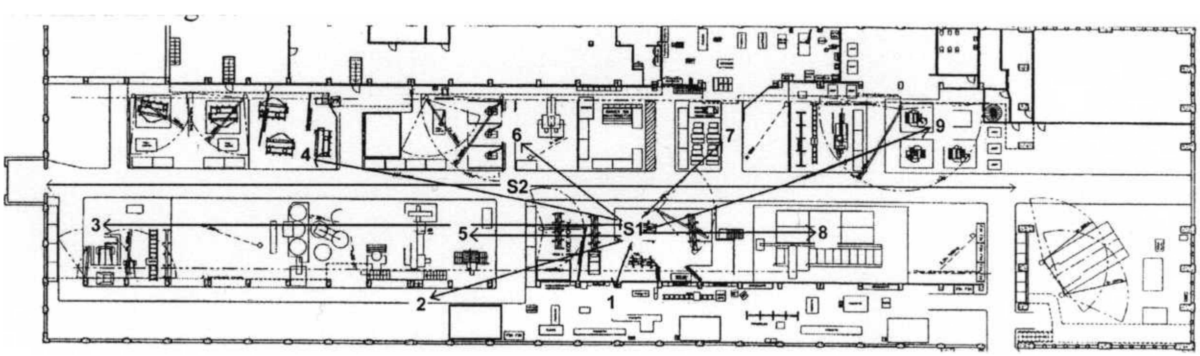

Figure 1: The source locations S1, S2 and the measurement points 1-9 in the workplace.

4 - RESULTS

4.1 - Reverberation time method

Averages of measured reverberation times in the workplace before and after the NCMs are presented in Table 1. The insertion loss IL was calculated using the formula $IL=10*\log_{10}(T_2/T_1)$, where T_1 and T_2 are the average reverberation times before and after the NCMs, respectively.

frequency (Hz)	T_1 (s)	T_2 (s)	IL (dB)
125	2.1	2.2	-
250	2.8	2.0	1.5
500	2.8	1.7	2.2
1000	2.8	1.5	2.7
2000	2.5	1.4	2.6
4000	1.9	1.1	2.3

Table 1: Measured reverberation times before and after the NCMs and calculated insertion loss.

4.2 - Spatial sound distribution method

The spatial sound distribution curves of the workplace before and after the NCMs are presented in Fig. 2. The calculated parameters DL_2 and DL_f are presented in Table 2. Increase of DL_2 and decrease of DL_f can be observed, which indicate that the acoustical environment of the workplace has improved.

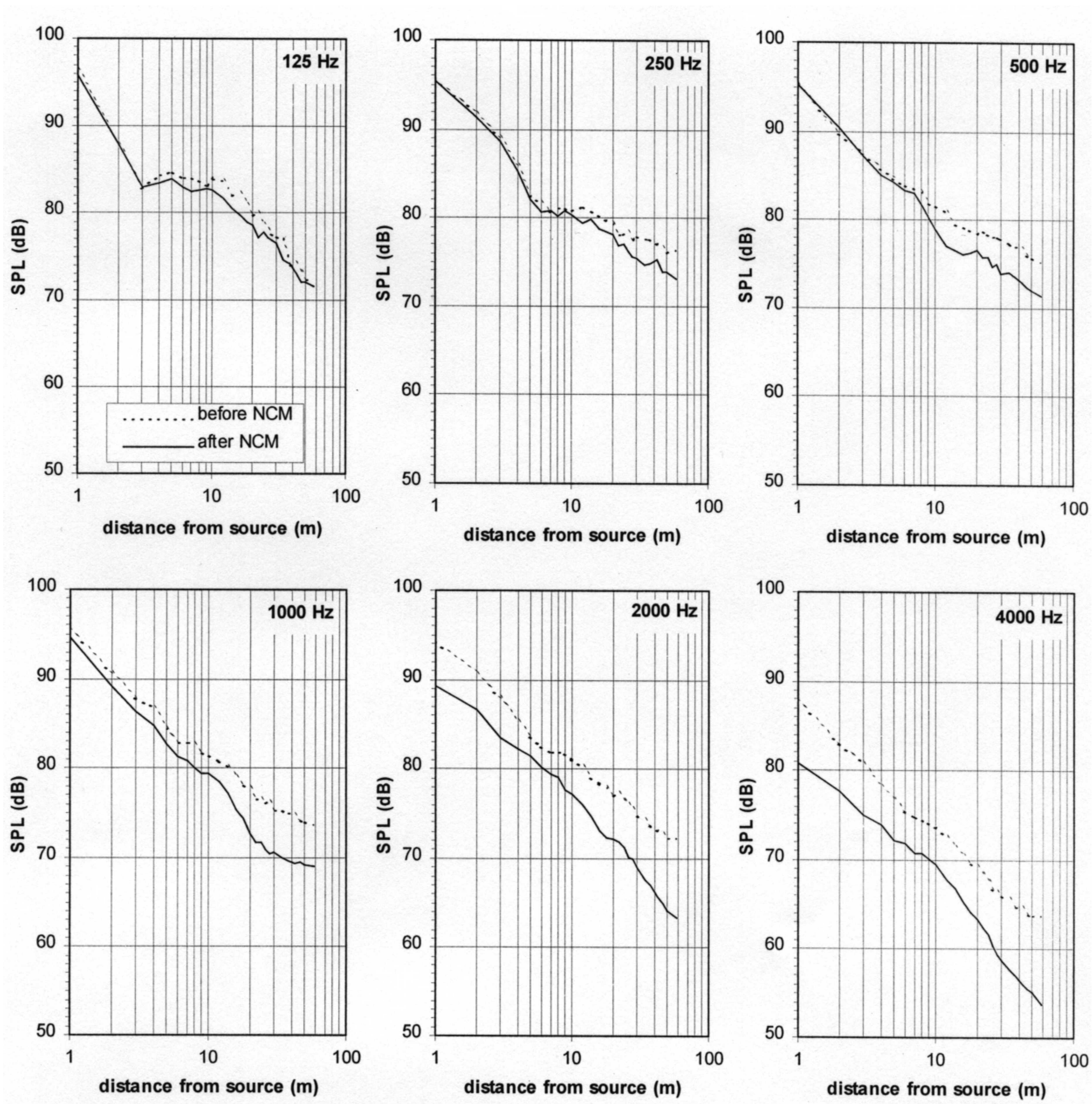

Figure 2: The spatial sound distribution curves of the workplace.

frequency	before NCM		after NCM	
(Hz)	DL_2 (dB)	DL_f (dB)	DL_2 (dB)	DL_f (dB)
125	2.1	8.7	2.6	7.3
250	2.0	6.4	2.4	5.4
500	3.1	6.9	4.1	4.8
1000	3.6	8.7	4.9	5.7
2000	3.2	8.6	4.6	4.2
4000	3.9	8.8	4.7	3.2

Table 2: DL_2 and DL_f parameters of the workplace.

4.3 - Insertion loss method (new method)

The calculated insertion loss values at the measurement points are presented in Table 3. The insertion loss values calculated from the spatial sound distribution results are presented in Table 4.

meas.point	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
1	0.4	1.3	1.6	2.7	3.4	4.2
2	0.9	3.1	3.9	5.5	3.9	4.9
3	4.5	6.0	10.7	10.8	10.4	11.8
4	4.5	6.4	8.0	10.3	9.6	10.6
5	3.7	2.9	3.8	4.6	5.1	5.5
6	5.2	0.8	3.5	4.3	3.1	4.1
7	1.3	0.3	5.1	6.6	7.7	8.7
8	2.8	3.8	6.5	7.7	8.0	8.8
9	2.5	3.1	6.3	9.5	9.9	11.6
average	**2.9**	**3.1**	**5.5**	**6.9**	**6.8**	**7.8**

Table 3: Insertion loss (dB) in the measurement points showed in Fig. 1.

range, m	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
4...12	1.2	0.7	1.5	2.1	3.2	4.2
13...24	1.8	1.3	2.7	4.2	5.2	5.7
25...50	1.0	2.4	3.6	5.2	6.8	7.8

Table 4: Insertion loss calculated from the spatial distribution method (Fig. 2).

5 - DISCUSSION

The reverberation time method yields only a rough underestimated approximation of the effect of the NCMs.

The DL_2 and DL_f parameters produced by the spatial distribution method may be useful for an acoustician. The sound distribution curves are valuable information at the design stage, especially when the demands for the acoustical environment of the workplace are known. However, the method is quite difficult to use in real workplaces, because the fittings are not considered. The insertion loss values shown in Table 4 were found to be more useful in operating workplaces than the DL_2 and DL_f parameters.

The new method shows the influence of the NCMs directly in decibels at work stations. The insertion loss results of the new method seemed to be higher than those measured according to ISO/CD 14257. The reason is that fittings etc. have an influence on the propagation of sound.

The new method is easy to use and takes into account fittings, screens and other obstacles that have an influence on sound propagation. It produces direct and simple information that customers are interested in. The new method was used in all 10 workplaces under investigation. According to our experience, this method is appropriate in all kinds of workplaces.

ACKNOWLEDGEMENTS

We would like to express our appreciation to The Finnish Work Environment Fund and the Ministry of Social Affairs and Health for financial support for this project.