inter·noise 83

# LOUDNESS AND ANNOYANCE OF LOW FREQUENCY SOUND

Shun'ichi NAKAMURA and Yasuo TOKITA

Kobayasi Institute of Physical Research
Kokubunji, Tokyo 185, JAPAN

## INTRODUCTION

In consideration of the influence of low frequency sound on the pollution problem, it is, in general, necessary to pay attention also to the other existing components of noise appearing in relatively higher frequencies, such as the associated partial tones, noise from other sources which can or cannot be specified. As seen in many actual cases, the pollution problem of low frequency sound is apt to be displaced by the dominant "noise", eventhough the low frequency sound in question is considerably more intense in its sound pressure level. The present report is concerned with the results of laboratory experiments related to that problem. This is our third paper following the two previous studies which have been presented at INTER NOISE 81 [1], [2].

## FACILITY

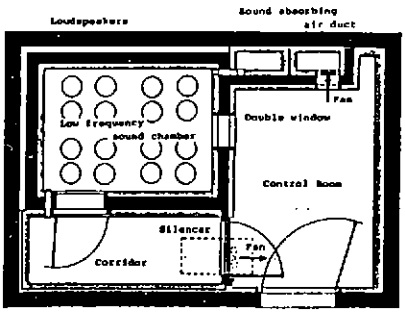



Fig.1

The experiments were conducted in the facility of the Kobayasi Institute of Physical research designed for investigations into low frequency sound exposure. As shown in Figure 1, sixteen 30cm loudspeakers in the ceiling can generate sound pressure in a chamber of 13m$^3$ down to the infrasound region.

## EXPERIMENT AND ANALYSIS

The method used here was intended to study the response of subjects statistically. Ideas very similar to our former experiments have been applied.

### Stimuli

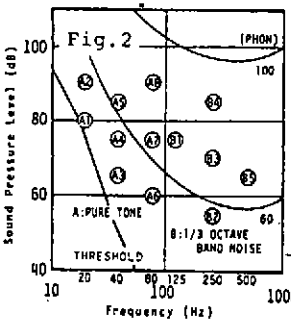
The test sounds used in this experiment were composed of two simultaneously presented components---A and B. A was a pure tone of low frequency and B was a one-third octave-band noise of mid frequency. Combining various cases of A and B which are shown in Figure 2, forty different test conditions were produced and presented successively to the subjects. The duration of each test sound was about 30s.

### Subjects

As shown in Table 1, the subjects were composed of students, housewives and business men. They had not reported any hearing or health problems.

### Experiment

Figure 3 shows the condition of the experiments. In each case, five to nine subjects sat together in the test chamber and immediately after each presentation of the test sound, they replied to four questions shown in Table 2. The first two questions are not critically important but rather designed to attract the subjects' attention.



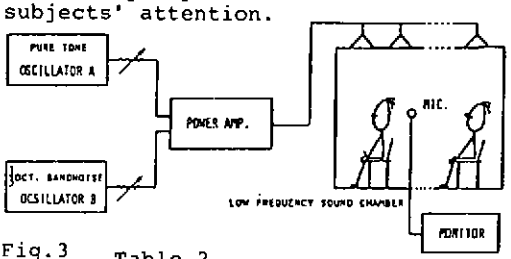




Fig.3

Table 1 SUBJECTS

| | |
|---|---|
| BUSINESS MEN | 14 |
| HOUSEWIVES | 8 |
| MALE STUDENTS | 12 |
| FEMALE STUDENTS | 11 |

Table 2 QUESTIONNAIRE

1. Do you detect a low frequency sound ?
(1-1) NO, (1-2) YES, (1-3) YES, VERY MUCH.

2. Do you detect a noise ?
(2-1) NO, (2-2) YES, (2-3) YES, VERY MUCH.

3. Which do you feel louder ?
(3-1) LOW FREQUENCY SOUND, (3-2) NOISE,
(3-3) BOTH SAMELY, (3-4) DIFFICULT TO ANSWER.

4. Which do you feel annoying ?
(4-1) LOW FREQUENCY SOUND, (4-2) NOISE,
(4-3) BOTH SAMELY, (4-4) DIFFICULT TO ANSWER.

Analysis

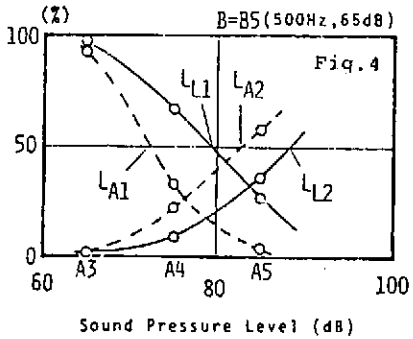
Figure 4 shows the procedure of the analysis. In the case of the comparison of B5 with A3, the subjects who responded "the noise is louder than the low frequency sound" (3-2) reached nearly 100%. With the increase of the level of the low frequency sound, responses decreased towards 0%. In this case, $L_{L1}$ which corresponds to 50% can be found between the levels of A4 and A5. In the case of $L_{L2}$, however, it is obtained by extracting a curve passing through the points given by the experiments. Four critical levels for the low frequency sound introduced here represent the following meanings respectively:

$L_{L1}$ ($L_{A1}$) : Below this level more than 50% of the subjects feel that the noise is louder (more annoying) than the low frequency sound in question.

$L_{L2}$ ($L_{A2}$) : Above this level more than 50% of the subjects feel that the low frequency sound is louder (more annoying) than the noise.

## CONCLUSIONS

The results of the analyses are shown in Figure 5. The sound pressure level between $L_{L1}$ and $L_{L2}$ can be related to the condition in which the low frequency sound would be perceived to be neither more nor less than the reference noise in regard to loudness, and the relation between $L_{A1}$ and $L_{A2}$ is the same in regard to the feeling of annoyance. Therefore, the frequency characteristics of the equivalent conditions of the low frequency sound against the noise can be approximately determined by taking the center line in the hatched zones in each figure. The followings can be observed in relation to the frequency characteristics of the level equivalent in perception:




REFERENCES

[1] S.Nakamura and Y.Tokita
INTER NOISE 81, 735

[2] Y.Tokita and S.Nakamura
INTER NOISE 81, 739

[3] B.W.Lawton
Langley Res. Center Rep.
(1975)

1) As for loudness, the curves obtained from the experiment are more gradual than those shown in ISO R 226 and the inverse "A-weighting" curve.
2) Our results on "loudness" almost agree with the equal "noisiness" curves given by B.W.Lawton [3] though his procedure in the experiments was quite different from ours. His experiments however, did not include such a high level as B4.
3) B1, B3 and B5 were expected to closely correspond. However, the case of B1 is different from the others in the lowest frequency.
4) A considerable difference in the equivalent level condition is found between "loudness" and "annoyance". The higher the region above the threshold level, the greater the difference. Regarding to "annoyance", much greater reduction of the sound pressure level might be required for the low frequency sound if it is not "louder" than the noise.
5) The bend appearing at 40Hz in the annoyance curve can be related to the wedge-like pattern of "feeling of vibration and oppression" presented by our former report.

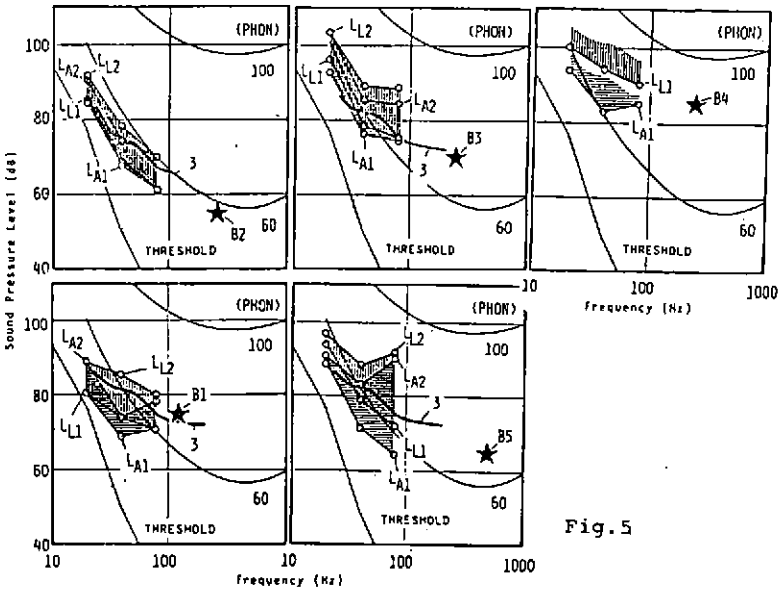



Fig.5