70/21

BRITISH ACOUSTICAL SOCIETY

OCCUPATIONAL HEARING LOSS

23-25 March 1970

HEARING LOSS DUE TO STEADY-STATE NOISE AND TO FLUCTUATING NOISE

by

Mrs. W. Passchier-Vermeer

Introduction

In 1966 the working group "Relation between noise and noise-induced hearing loss" of the Research Committee on Occupational Health TNO started an investigation on the effect of noise during working hours on the hearing of people exposed to it. The investigation was restricted at first to the effect of steady-state broadband noise and continuous exposure during 8 hours a day, for at least 5 days a week. The results of this work have been published in 1968 [1]. Then the investigation was extended to situations with fluctuating noise levels; the exposure still being 8 hours a day for 5 days a week. This work was not started before 1969, and at the moment that this text had to be sent in only one example was available of the effect of fluctuating noise on the hearing levels of people exposed to it. At the time of the lecture, however, more data will be available.

In this paper we give:

- the relations between noise and noise-induced hearing losses due to continuous exposure for 8 hours a day, at least 5 days a week
- the disagreement of these relations with the principle of equal sound immission over long exposure periods
- results of noise- and audiometric measurements in one industry with fluctuating noise levels.

Continuous exposure to steady-state noise

Data have been collected from the available literature as well as from measurements by members of our working group. Together they relate to 20 groups of employees: all in all about 4600 people.

Each noise has been characterized by the noise rating number (NR) of its octave band spectrum in the frequency range of 500 to 2000 Hz [2]. This NR is equal to the number of the NR-curve that is just not surpassed by any of the octave band levels with mid-frequencies 500, 1000 and 2000 Hz of the octave band spectrum of the noise. Although the results are formulated in NR-terms, they can be used with reasonable accuracy for sound levels in dB(A) too; the number obtained by adding 5 to the NR-value is numerically equal to the corresponding sound level in dB(A).
The noise-induced shift of the median hearing level at a certain frequency of a group of people exposed to noise, i.e. the difference between the median hearing level of that group and the median hearing level of a non-noise exposed group with the same mean age as the exposed group, is indicated by $D_{50\%}$. In Fig. 1, for a number of frequencies and for an exposure time of 10 years,

$D_{50\%}$ is given as a function of NR. Fig. 2 gives an example of $D_{50\%}$ for a longer exposure time: 40 years. From comparison of both figures it is clear that the increase of $D_{50\%}$ with exposure time is not the same for all frequencies. The available material led to the following conclusions:

- for each of the frequencies 500, 1000, 2000 and 3000 Hz and for exposure times longer than 10 years the increase of $D_{50\%}$ per year is equal to a NR-independent percentage of the $D_{50\%}$ due to an exposure of 10 years;
- for 4000 Hz there is no increase at all after 10 years exposure;
- for 6000 Hz and 8000 Hz the situation is more complicated: for NR's up to 92 there is no increase either, whereas for NR's larger than 92 the increase depends on the NR.

In the following Table the results are summarized.

Table

Increase per year of $D_{50\%}$ for exposure times longer than 10 years, in percentage of $D_{50\%}$ due to exposure for 10 years

500 Hz	1000 Hz	2000 Hz	3000 Hz	4000 Hz	6000 Hz	8000 Hz
2%	2,5%	10%	1%	0%	0.3(NR-92)% 0% for NR<92	0.3(NR-92)% 0% for NR<92

From Fig. 1 and the Table given above it is possible to calculate $D_{50\%}$ for all exposure times between 10 and 40 years and all NR's between 75 and 98.

Besides the noise-induced shifts of the <u>median</u> hearing levels $D_{50\%}$, also the noise-induced shifts of the hearing levels not exceeded in 90%, 75%, 25% and 10% of the people exposed have been determined. These noise-induced shifts (indicated by $D_{x\%}$ with x equal to 90, 75, 25 and 10) are, analogously to $D_{50\%}$, each equal to the difference between the hearing level not exceeded by x percent of the people exposed and the hearing level not exceeded by the same percentage of non-noise exposed people, with the same mean age.

Our analysis showed that for exposure times of at least 10 years, $D_{x\%} - D_{50\%}$ (for x = 90, 75, 25, 10) is independent of exposure time for all frequencies considered, but depends upon the NR. The results are presented in Fig. 3. If $D_{90\%}$, $D_{75\%}$, $D_{50\%}$, $D_{25\%}$ and $D_{10\%}$ show no or only slight differences, this means that the spread in hearing levels of people exposed is about the same as that of non-exposed people, although the absolute values of the hearing levels depend on the noise of course.

For some years now, the assumption of "equal sound immission" is in the picture. For continuous exposure of 8 hours a day and 5 days a week to steady-state broadband noise this implies that in all circumstances with equal values of NR + 10 log T (where T is total exposure time in years) the noise-induced shifts of the median hearing levels should be the same. This is not confirmed by our results for any frequency. To give one example: $D_{50\%}$ at 4000 Hz is for NR 92 and T = 40 years equal to 30 dB; for NR 98 and T = 10 years equal to 50 dB. This is a difference of 20 dB: according to the principle of equal sound immission , however, the difference should have been zero. Although our results seem to contradict the principle of equal sound immission over years, it might be correct for a daily period, i.e. the daily sound immission may be decisive for the resulting hearing losses. Therefore our working group decided to work along these lines to rate

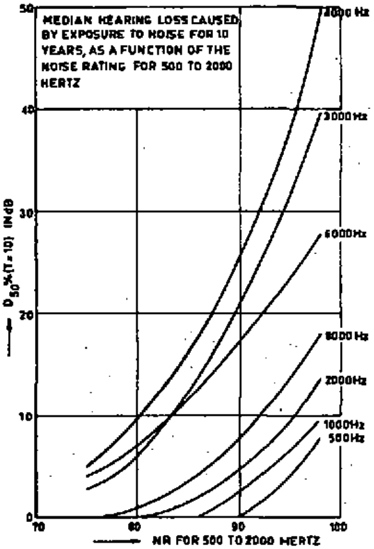

Fig. 1

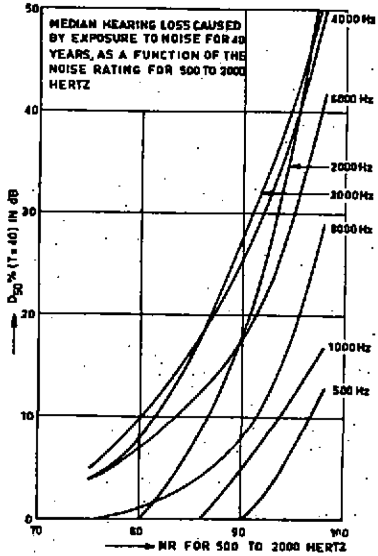

Fig. 2

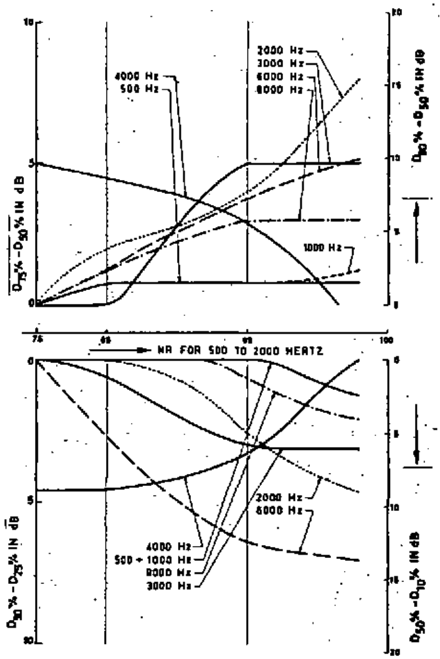

Fig. 3

Fig. 4

fluctuating noise. To that end we introduced an equivalent sound level L_{eq}, defined as:

$$L_{eq} = 10 \log \frac{1}{T_2-T_1} \int_{T_1}^{T_2} 10^{L_p/10} \, dt,$$

where L_p is the momentary sound level in dB(A), T_1 and T_2 the begin and end of an 8 hours working day. The Institute for Applied Physics TNO-TH (mr. Kleinhoonte van Os and cooperators) constructed equipment to measure directly the integral over any period longer than one minute. This equipment will be and has been used to measure fluctuating sound levels. The whole idea of an equivalent sound level for fluctuating noise would be nonsense, if the increases of the median hearing levels with exposure time at all frequencies of people exposed to fluctuating noise would not be identical to those of people exposed to steady-state noise. This has been checked with some median audiograms of people working in very fluctuating noise (foundry-noise, riveting), At least in these cases the increases of the median hearing levels with time are indeed identical to those for continuous exposure to steady-state noise. The spread in the hearing levels has not been considered up till now.

Up till Nov. '69, L_{eq} has been measured only for one situation and the corresponding audiograms have been examined. The group consists of 144 machine wood-workers, with exposure times of at least 10 years and without ear diseases and previous noise exposure. They have been split up in subgroups according to exposure time (10-19, 20-29, 30-39, $\geqslant$40 years). In Fig. 4 the noise-induced shifts of the median hearing levels of these subgroups are shown. At 1000 Hz and below, hearing levels have been measured only 15 dB above normal hearing and as most people had better hearing, no median values could be determined at 1000 Hz and below. Comparing Fig. 4 with Fig. 1 and the Table, it turns out that at each frequency seperately the noise-induced shifts of the median hearing levels of the subgroups are equal to those for NR 93 to NR 94 with continuous exposure to steady-state noise. NR 93 to NR 94 corresponds with a sound level of 98 to 99 dB(A). The measured values of L_{eq} were between 98.4 and 100.6 dB(A), depending upon the place of measurement. Taking into account the accuracy of audiometric measurements, and of noise measurements, these figures agree very well. To give an impression of the fluctuations of the noise: for the place where over the whole day the equivalent sound level was 100.6 dB(A), the equivalent sound levels determined per quarter of an hour were for about one third of the time around 103 dB(A), for the rest of the time around 98 dB(A).

Although there is a good agreement between noise measurements and audiometric measurements in this case, we want to investigate whether it is possible to rate fluctuating noise by an equivalent sound level in situations, where the sound level fluctuations are larger.

---

[1] Hearing loss due to exposure to steady-state broadband noise. Report nr. 35 of the Research Institute for Public Health Engineering TNO.

[2] Community Reaction Criteria for External Noises, by C.W. Kosten and G.J. van Os. The Control of Noise, p. 373, H.M.S.O., London 1962.