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HEARING THRESHOLD LEVELS AND NOISE-INDUCED HEARING LOSS IN THE BUILDING INDUSTRY, IN RELATION TO HEARING THRESHOLD LEVELS OF REFERENCE GROUPS

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CONTENTS

SUMMARY

The results of a second order regression analysis on the hearing threshold levels of a reference population (of about 450 male otologically unscreened subjects, who did never have a noisy occupation) are given.
The audiometric tests performed on this reference population were identical to those on more than 7000 workers in the building industry. It was shown that relations between hearing threshold levels and age of the (B.I.) reference population are nearly equal to those of data base A of ISO/DIS 1999.1, with the exception of the hearing threshold levels ($A_{0,10}$), just exceeded in 10% of the population, at 3000, 4000 and 6000 Hz. There, the $A_{0,10}$-values of the (B.I.) reference group are 6 to 10 dB higher than those of data base A, irrespective of age.

Damage-equivalent noise exposure levels, relative to the B.I. reference group, were calculated for several occupational groups in the building industry, such as painters, bricklayers, concretors, carpenters, crane-drivers, stone-chippers, clerical staff. The hearing threshold levels of the last group correspond to those of the B.I. reference group.

Following the German study on the hearing of workers in the building industry and using the group of painters as reference population, damage-equivalent noise exposure levels relative to that population were calculated as well. This resulted for bricklayers in damage-equivalent noise exposure levels of 84 dB(A), for concretors in 85 dB(A), for carpenters in 85,5 dB(A), for crane-drivers in 87,5 dB(A), for stone-chippers in 93 dB(A).

The hearing threshold levels of the painters in the German study correspond closely to those of the study in the Netherlands.

It is concluded that only further research may clarify the observed differences in hearing threshold levels of painters compared to those of the B.I.-reference group and may solve the question which population may serve as a reference data base for workers in the building industry.

1. INTRODUCTION

In the period from September 1982 until January 1985 the TNO Institute of Preventive Health Care coordinated an investigation on the hearing of workers in the building industry. The aims of the project were to standardize procedures and audiometric test methods at all 44 regional occupational health centres cooperating in the project and to establish hearing threshold levels and hearing loss due to noise exposure of workers in the building industry.

This paper relates to the question of hearing threshold levels of groups of people not exposed to noise, the so-called reference groups. These hearing threshold levels have to be known in order to be able to determine which part of the hearing threshold levels of the workers in the building industry are induced by noise and which part is due to other causes, such as ageing.
Together with an audiometric test of more than 7000 persons working in the building industry, 445 persons of a reference group were examined. The reference group consisted of male subjects, without a noisy occupation at present or in the past. The reference group was not otologically screened. The subjects of the reference group were tested with the same equipment, by the same persons and in the same test environments as those working in the building industry. Audiometric tests were carried out in accordance with the specifications of ISO 6189, with ambient sound pressure levels in the various test rooms, allowing hearing threshold level measurements from o dB HL re ISO 389 and in some test rooms from -5 or -10 dB HL. Far the most of the audiometric tests were carried out with continuous sweep frequency audiometers (type Peekel). It has been shown (Passchier-Vermeer, 1979) that this audiometric test method gives on the average the same test results as the

methods described in ISO 6189.

In the framework of a project, in which hearing conservation programs in industry were developed and carried out by a TNO noise team, hearing threshold levels were related to noise exposure level (L_{EX}) (Passchier-Vermeer, 1985). The relations were based on noise measurements and audiometry with respect to 2400 male workers. Audiometry was performed by using Madsen MTA 86 audiometers. By using the same audiometric equipment in the same test environment by the same audiometricians, also the hearing threshold levels of a group of 500 male subjects without a noisy occupation in the present and past were established. This 'reference' group for the industrial workers is referred to as the TNO reference group (Passchier-Vermeer, 1985). From an analysis of the hearing threshold levels as a function of age of the otologically unscreened TNO reference group it was shown that these hearing threshold levels correspond to those given in data base A of ISO 7029 and of ISO/DIS 1999.1 (and 1999.2).

2. HEARING THRESHOLD LEVELS OF THE B.I.-REFERENCE GROUP

The hearing threshold levels of the B.I.-reference group were determined as a function of age. The test subjects were grouped according to age into classes of 5 year width. The same types of formulae were used as in ISO/DIS 1999.1 for data base A, and the appropriate constants and parameters were determined using a second order regression analysis. The following formulae were used:

$$A_{0,50;y} = a\,(y-18)^2 + A_{0,50;18} \qquad ((1))$$

in which

$A_{0,50;y}$: median hearing threshold levels at an age of y years

y: age in years

a: coefficient dependent upon frequency

$$A_Q - A_{0,50} = k\,S_u \qquad 0,05 < Q < 0,50 \qquad ((2,a))$$

$$A_{0,50} - A_Q = k\,S_\ell \qquad 0,50 < Q < 0,95 \qquad ((2,b))$$

$$S_u = b_u + c_u\,A_{0,50} \qquad ((2,c))$$

$$S_\ell = b_\ell + c_\ell\,A_{0,50} \qquad ((2,d))$$

k: dependent upon Q. For:

Q = 0,75 and 0,25 k = 0,675

Q = 0,10 and 0,90 k = 1,282

In table 1 the values of a and $A_{0,50;18}$ are given, together with values from data base A of ISO/DIS 1999.1. (p. 4).

From the data, the best fitting straight lines have been calculated of $\frac{A_Q - A_{0,50}}{k}$ against $A_{0,50}$ for k = 0,675 and k = 1,282. This results in an average value of c_u of 0,622. Using this value at each frequency, the best fitting straight lines of

Table 1. Values of a and $A_{0,50;18}$ of the second order regression curves.

Frequency in Hz	Reference group building industry		ISO/DIS 1999.1	
	$A_{0,50;18}$	a	$A_{0,50;18}$ *)	a
500	+1,16	0,005	0	0,0035
1000	-1,02	0,005	0	0,004
2000	-0,30	0,008	0	0,007
3000	+1,81	0,010	0	0,0115
4000	+3,97	0,014	0	0,016
6000	+6,66	0,015	0	0,018

* In ISO/DIS 1999.1, $A_{0,50;18}$ has been taken as 0 dB. From the relevant literature (Robinson, 1978) it turned out that $A_{0,50;18}$ at 500, 1000, 2000, 3000, 4000, 6000 Hz is 0,2, -0,1, -0,2, 2,2, 3,1 and 11,9 dB respectively.

$\frac{A_Q - A_{0,50}}{k} = b_u + 0,622\ A_{0,50}$ have been determined, thus giving the values of b_u. These values of b_u are given in table 2. The same procedure has been applied for $Q > 0,50$. It turned out that c_ℓ is equal to 0,473. The values of b_ℓ have been included in table 2, together with the relevant values from data base A.

Table 2. b_u and b_ℓ for the reference group of the building industry and for data base A of ISO/DIS 1999.1.

Frequency in Hz	Reference group building industry (c_u = 0,622; c_ℓ = 0,473)		ISO/DIS 1999.1 data base A	
	b_u	b_ℓ	b_u	b_ℓ
500	6,36	4,43	6,12	4,89
1000	7,49	4,04	6,12	4,89
2000	7,38	4,53	7,23	5,78
3000	10,90	3,89	7,78	6,23
4000	9,81	4,16	8,34	6,67
6000	8,15	5,05	9,45	7,56

In the figures 1 to 6, hearing threshold levels of the B.I.-reference group have been plotted as a function of age.

In table 3, at the end of this report, values of A_Q have been given for mean ages of 20, 30, 40, 50 and 60 years and for fractiles of 0,90, 0,75, 0,50, 025 and 0,10.

In the figures 7 to 12, the hearing threshold levels of the B.I.-reference group have been compared with those from data base A, the example of data base B of ISO/DIS 1999.1 and the TNO reference group. When curves of the B.I.-reference group are invisible, they correspond to those of the TNO reference group. In these figures $A_{0,50;18}$ of data base A have been taken equal to zero.

3. DAMAGE-EQUIVALENT NOISE EXPOSURE LEVELS RELATIVE TO THE B.I.-REFERENCE GROUP

Using the hearing threshold levels of the B.I.-reference group as a reference data base, "damage-equivalent noise exposure levels (L'_{EX})" were determined for groups of workers from the building industry, having a specific profession. To that aim, the following method was used.

The relation between hearing threshold level (H) of a noise-exposed group, noise-induced hearing loss (N) and hearing threshold level (A) of a reference group is taken as:

$$H = A + N \qquad ((3))$$

In ISO/DIS 1999.1, N is given as a function of frequency, exposure time T and noise exposure level L_{EX} for fractiles of N from 0,05 to 0,95. In table 4, at the end of this report, N is given for L_{EX}-values of 80, 85, 90 and 95 dB(A), for fractiles of 0,90, 0,75, 0,50, 0,25 and 0,10 and exposure times of 2, 10, 20, 30 and 40 years. In this table, N is the sum of the N-values at the six frequencies 500, 1000, 2000, 3000, 4000 and 6000 Hz.

Each group of subjects, having the same specific profession, was splitted up into subgroups according to age (and accordingly to exposure time T, since age and exposure time have in this study on the average a difference of 19 years), in age-classes of 10 years. For each subgroup, $H_{0,50}$ was determined if the number of test subjects was 10 or more, $H_{0,25}$ and $H_{0,75}$ were also determined if the number was 20 or more, $H_{0,10}$ and $H_{0,90}$ were caculated for subgroups of at least 40 persons. Then, for each subgroup, the sum was determined of the H-values at the six frequencies mentioned earlier and from that result, the sum of the 6 A-values of the reference group at the same mean age as the subgroup was subtracted. Then, the resulting value (of H - A) was compared with the N-values, such as given in table 4, using the correct exposure time T, to determine which L'_{EX}-value would have caused the resulting value of H - A. This L_{EX}-value is called the damage-equivalent noise exposure level (L'_{EX}).

Before applying this method to the various professional groups, the data of these groups and subgroups with in total 6827 workers have been analysed with the following results (Passchier-Vermeer, 1984):

- the L'_{EX} -values at the seperate frequencies 2000, 3000, 4000 and 6000 Hz are independent of frequency. The difference between the average L'_{EX}-value at the different frequencies and the total average L'_{EX}-value (based on 6827 workers) turned out to be +0,18 dB(A) at 2000 Hz, +0,21 dB(A) at 3000 Hz, -0,50 dB(A) at 4000 Hz and +0,10 dB(A) at 6000 Hz. No analysis based on L'_{EX}-values at 500 and 1000 Hz has been carried out, because N is zero or small in the relevant L'_{EX}-range (N is zero at 500 Hz for values of L'_{EX} of 93 dB(A) and less and at 1000 Hz for 89 dB(A) and less). Therefore small positive deviations of N from zero give rise to very high L'_{EX}-values, whereas L'_{EX} might as well be 20 dB(A) or more lower, due to the incertainties in N.

- the L'_{EX}-values at the different fractiles are independent upon the fractiles. The difference between the mean L'_{EX}-values at the seperate fractiles and the total mean L'_{EX}-value is at 0,90 equal to -0,03 dB(A), at 0,75 -0,68 dB(A), at 0,50 +0,43 dB(A), at 0,25 -0,36 dB(A) and at 0,10 equal to +0,64 dB(A).

- the L'_{EX}-values are independent upon age. The difference between the mean L'_{EX}-value in an age-class and the total mean L'_{EX}-value is equal to -0,64 dB(A) at an age of 25 to 34 years, at 35 to 44 years equal to -0,60 dB(A), at 45 to 54 years equal to +0,38 dB(A) and at an age of 55 to 65 years equal to 0,86 dB(A).

- based on the foregoing three results, it is justified to calculate L'_{EX}-values as the mean value of the various L'_{EX}-values, irrespective of frequency, fractile and age.

In table 5 the damage-equivalent noise exposure levels, relative to the B.I.-reference group, are given for the largest professional groups in the study and for the three professional groups with the highest damage-equivalent noise exposure levels, i.e. the rammers, metal workers and stone-chippers. Between brackets, the damage-equivalent noise exposure levels are given of those workers who had only one profession during their entire professional career up to the time of testing.

Table 5. Damage-equivalent noise exposure levels of various occupational groups, relative to the B.I.-reference group.

Profession	Number of workers tested	L'_{EX} (in dB(A)* **	
Clerical staff	176	-	(-)
Building technicians	294	85	(-)
Painters	388	88	(88)
Executors	548	88	(89)
Stucco-workers	183	90	(87)
Bricklayers	631	91	(90)
Concretors	207	91	
Carpenters	1675	91	(91)
Carpenters in factories	154	93	
Navvies	292	91	(91)
Crane-drivers	132	92	(94)
Rammers	41	96	
Metal workers	41	96	
Stone-chippers	15	97	

* Values between brackets refer to those workers, who had only one profession during their entire professional career before audiometric testing.

** If L'_{EX}-values would have been derived from the formula $H=A+N-\frac{A.N}{120}$, as postulated in ISO/DIS 1999.1, then these values would have been slightly larger. Whole numbers would deviate at most 1 dB(A) from the figures.

4. HEARING THRESHOLD LEVELS OF PAINTERS

In an extensive German study (Pfeiffer, 1985), an analysis is made of hearing threshold levels of large groups of masons, pipe-fitters, concretors, carpenters, painters and varnishers. In the study it was shown that most consistent results were obtained, if the group of painters and varnishers were used as a reference group. The results turned out to be less consistent if data bases A or B of ISO/DIS 1999.1 were chosen.

To compare the results of the present study with those of the larger German one, first the data of the hearing threshold levels of the painters have been analysed. In this respect, the same method of analysis has been applied as was used with the B.I.-reference group. The results, concerning $A_{0,50;18}$, a, b_ℓ, b_u, c_ℓ and c_u given in table 6.

Table 6. Values of $A_{0,50;18}$, a, b_ℓ, b_u, c_ℓ and c_u of painters.

Frequency in Hz	$A_{0,50;18}$	a	b_u	c_u	b_ℓ	c_ℓ
500	3,25	0,0040	9,35	0,212	5,43	0,294
1000	1,76	0,0048	3,29	1,515	2,30	0,765
2000	1,63	0,0092	6,49	0,828	2,24	0,656
3000	6,66	0,0125	4,59	0,894	3,51	0,561
4000	8,14	0,0189	13,24	0,446	0,19	0,728
6000	9,48	0,0196	13,85	0,331	0,34	0,611

In table 7, at the end of this report, the smoothed values of the hearing threshold levels of the group of painters are given for ages of 20, 30, 40, 50 and 60 years.

In table 8, at the end of the report, the differences between the hearing threshold levels of the painters and the B.I.-reference group are given.

5. DAMAGE-EQUIVALENT NOISE EXPOSURE LEVELS; RELATIVE TO THE GROUP OF PAINTERS

If the hearing threshold levels of the painters are used as a reference data base, then damage-equivalent noise exposure levels of the various professional groups can be calculated according to the method,given earlier, with the B.I.-reference group as the reference group. Without further comment, the result is given in tabel 9.

Table 9. Damage-equivalent noise exposure levels, relative to the group of painters and relative to the B.I.-reference group (see table 5).

Profession	Number of workers tested	L'_{EX} relative to painters	L'_{EX} relative to B.I. reference group
Clerical staff	176	-	-
Building technicians	294	-	85
Painters	388	-	88
Executors	548	-	88
Stucco-workers	183	83	90
Bricklayers	631	84	91
Concretors	207	85	91
Carpenters	1675	85,5	91
Carpenters in factories	154	88,5	93
Navvies	292	87	91
Crane-drivers	132	87,5	92
Rammers	41	92	96
Metal workers	41	92	96
Stone-chippers	15	93	97

6. DISCUSSION

The most amazing result of the analysis is the difference between hearing threshold levels of the painters and those of the B.I.-reference group. If this difference is expressed in terms of damage equivalent noise exposure levels, then the diffference is due to an L'_{EX}-value of 88 dB(A). This value is based on the assumption that the relations in ISO 1999.1 between noise-induced hearing loss N and noise exposure level L_{EX} are correct. Although results of sound level measurements with regard to painters are lacking at the moment, it seems rather unlikely that painters are exposed to noise with noise exposure levels of 88 dB(A). On the other hand, the observed difference between hearing threshold levels of the painters and the B.I.-reference group is not caused by audiometric-related causes, since all relevant audiometric factors were the same in the testing of both groups of subjects.

In this respect the following considerations might be of importance.

1) In the study, the hearing threshold levels of the clerical staff of building undertakings have been established. Comparing these hearing threshold levels of this occupational group without evident occupational noise exposure with those of the B.I.-reference group and the painters gives the following result. To that aim the sum is taken of all H-values (for fractiles 0,90, 0,75, 0,50, 0,25 and 0,10 and for frequencies 500, 1000, 2000, 3000, 4000 and 6000 Hz, i.e. 30 values of H) of a subgroup. These total H-values are given in table 10 as a function of age (p. 12).

Table 10 shows a very good agreement between the hearing threshold levels of the B.I.-reference group and the clerical staff. This supports the correctness of the B.I.-reference group data.

Table 10. Sum of hearing threshold levels (in dB) at 30 combinations of fractiles and frequencies as a function of age.

Group	Age in years				
	20	30	40	50	60
B.I.-reference group	113	155	256	421	644
Clerical staff	-	142	310	430	518
Painters	226	273	387	574	826

2) The agreement between the results of the German study on the hearing of painters (the so called data base of "Malern und Lackierern"(M + L)) and our study is very good. In this repect the data of table 8 of this report were compared with table 13 of the German study. The result is given in table 11 at the end of this report.

At an age of 20 years small differences exist between the median hearing threshold levels of both groups of painters. These small differences may be (partly) due to audiometry-related causes, such as differences in acoustic environment during testing and in audiometric test methods. If this possibility is accepted and the differences are adjusted accordingly, then the result gives an even better agreement between the German and Netherlands study, as is shown in table 12, at the end of the report.

This observation supports the correctness of the hearing threshold levels of the group of painters.

3) In the industrial study (Passchier-Vermeer, 1985) it was observed that differences exist between the hearing threshold levels of workers, at the time of testing exposed to occupational noise with noise exposure levels of less than 80 dB(A),and those of the TNO reference group. In table 13, these differences (ΔH) are given for fractiles 0,90, 050 and 0,10. In this group of workers, pre-

sently exposed to noise exposure levels of less than 80 dB(A), subjects were included with occupational noise exposure in former jobs. The effect on the hearing threshold levels of this occupational noise exposure in the past is according to TNO-Report B 610 (Passchier-Vermeer, 1984; table 13 modified) as given in table 13 of this report. Comparing the upper part of table 13 with the lower part, it can be concluded that the differences, observed in the group of workers with an L_{EX}-value of less than 80 dB(A), relative to the TNO reference group, can be fully explained by noise exposure in previous jobs of the group of industrial workers. Therefore, the discrepancy observed in the industrial study between the TNO reference group and the group of workers with noise exposure levels of 80 dB(A) and less, is explained by past noise exposure.

From the industrial study it turned out that ΔH is independent of age and exposure time, for ages of 30 years and over and exposure times of 10 years and more. The mean age of the population studied was about 42 years. Also, the mean age of the population from the building industry was about 40 years. Results are therefore most reliable at those ages. Therefore, the differences between the hearing threshold levels of the painters relative to the B.I.-reference group are reproduced in table 14 at the end of this report for a mean age of 40 years.

Comparing the upper part of table 13 with table 14 shows that the corresponding differences are quite similar. This could be considered as circumstantial evidence that noise exposure might have affected the hearing of painters. Since it is quite unlikely that this noise exposure is due to occupational manipulations by the painters themselves during their worktime, the hearing losses might be caused by job-related noises, such as from manipulations in the environment by workers with other professions and/or from radio's etc. and by noise exposure during leisure time. In that respect, both types of noise exposure might interfere, thus resulting in hearing losses which are larger than could be expected from the seperate noise exposures. However,this last explanation should be considered as mere speculation, until future research might prove its correctness.

4) The question whether the hearing threshold levels of the occupational groups should be considered relative to those of the B.I.-reference group or those of the painters can, in principle, also be answered from noise exposure data as such. To that aim, some results of noise measurements are given in the German study. As fas as applicable, the results are given in table 15, together with some L'_{EX}-values.

Table 15. Results of sound level measurements and of L'_{EX} of several professional groups.

Occupational group	Range of L_{Aeq}-values	L'_{EX} relative to painters	L'_{EX} relative to B.I.-reference group
Bricklayers	81 - 85,5	84	91
Concretors	86 - 92	85	91
Carpenters	84 - 95	85,5	91

From table 15 no definite conclusion can be drawn, due to the wide variation in the measured equivalent sound levels. However, further analysis of already existing measuring results and of further measurements of noise exposure levels of several occupational groups might lead to definite conclusions.

Another item, which gives rise to international discussions, concerns the audiometric zero, according to ISO 389. This audiometric zero is based on modal values of hearing threshold levels of groups of otologically screened populations within the age limits of 18 to 30 years inclusive. The populations studied in this report concern otologically unscreened populations. The difference between the median hearing threshold level of otologically unscreened and otologically screened populations is only 0,3 dB at 500, 1000 and 2000 Hz and 0,8 dB at 3000, 4000 and 6000 Hz. At the same time, there exists only a small difference between median and modal values of the hearing threshold levels since the distribution of the hearing threshold levels of the (young) population under consideration is nearly normal(Gaussian). In table 16, the median hearing threshold levels of several reference groups are given for a mean age of 18 years.

Table 16. The median hearing threshold level at an age of 18 years ($A_{0,50;18}$) of various otologically unscreened groups.

	Modified* data base	TNO reference group	B.I.- reference group	Painters	M+L data base	BIA data base modified**
500	0,5	1,7	1,2	3,3	7,7	5,6
1000	0,2	1,2	-1,0	1,8	5,7	2,9
2000	0,1	0,2	-0,3	1,6	6,8	4,9
3000	3,0	0,5	1,8	6,7	8,5	3,6
4000	3,8	1,0	4,0	8,1	8,5	4,4
6000	12,7	2,7	6,7	9,5	10,8	8,0

* According to ISO 7029, data base A is a data base for otologically screened populations. According to Passchier-Vermeer (1985) the difference between median hearing threshold levels of otologically unscreened and otologically screened populations is at 500, 1000 and 2000 Hz equal to 0,3 dB and at 3000, 4000 and 6000 Hz equal to 0,8 dB.

** From the present study, the differences between the B.I.-reference group and the painters can be calculated. These differences can be used to estimate the median hearing threshold levels of a BIA-data base, comparable to the B.I.-reference group, but established with other audiometric factors.

7. CONCLUSION

The analysis of two sets of data, one concerning industrial workers and the TNO reference group and the other concerning workers in the building industry and the B.I.-reference group, gives the following results:

- the hearing threshold levels of the otologically unscreened TNO reference group are nearly identical to those of data base A of ISO/DIS 1999.1 and can be used as a reference data base for industrial workers, if audiometry is performed according to the specifications of ISO 6189.
- the hearing threshold levels of the otologically unscreened B.I.-reference group are nearly identical to those of the TNO reference group, with the exception of $A_{0,10}$ at 3000, 4000 and 6000 Hz. At those frequencies, the $A_{0,10}$-values of the B.I.-reference group are 6 to 10 dB higher than those of the TNO reference group.
- the damage-equivalent noise exposure levels (L'_{EX}), calculated relative to the B.I.-reference group, of groups of workers in the building industry seem rather high. For instance, painters have a L'_{EX}-value of 88 dB(A), bricklayers, concretors and carpenters values of 91 dB(A).
- if, following the German example, the hearing threshold levels of the group of painters is taken as a reference data base, then the damage-equivalent noise exposure levels of bricklayers is equal to 84 dB(A), of concretors 85 dB(A) and of carpenters 85,5 dB(A).
- at the time being, it is not clear which causes are the basis of the differences between the hearing threshold levels of painters and those of the B.I.-reference group.

Only further research may show which data base may serve as a reference data base for workers in the building industry and may clarify the differences between hearing threshold levels of painters and of the B.I.-reference group.

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TABLES

3, 4, 7, 8, 11, 12, 13, 14

Table 3. Hearing threshold levels of B.I.-reference group.

Mean age in years	Fractile	Frequency in hertz 500	1000	2000	3000	4000	6000
20	0.90	-5,2	-5,6	-5,9	-4,3	-3,8	-3,8
	0.75	-2,2	-3,4	-3,2	-1,4	-0,1	1,2
	0.50	1,2	-1,0	-0,3	1,9	4,0	6,7
	0.25	6,0	3,6	4,6	10,0	12,3	15,0
	0.10	10,3	7,8	9,0	17,3	19,8	22,5
30	0.90	-4,9	-5,3	-5,5	-3,7	-3,01	-3,0
	0.75	-1,7	-2,9	-2,5	-0,4	1,2	2,6
	0.50	1,9	-0,3	0,9	3,3	6,0	8,8
	0.25	7,0	4,6	6,2	12,0	15,1	18,0
	0.10	11,5	9,1	11,0	19,8	23,3	26,3
40	0.90	-4,3	-4,6	-4,4	-2,4	-1,1	-1,0
	0.75	-0,6	-1,8	-0,6	1,9	4,5	6,1
	0.50	3,6	1,4	3,6	6,7	10,8	13,9
	0.25	9,4	7,0	10,1	16,8	21,9	25,3
	0.10	14,6	12,1	15,9	25,9	31,9	35,5
50	0.90	-3,2	-3,6	-2,7	-0,2	1,9	2,2
	0.75	1,3	0,1	2,3	5,6	9,7	11,6
	0.50	6,3	4,1	7,9	12,1	18,3	22,0
	0.25	13,2	10,9	16,2	24,5	32,6	36,8
	0.10	19,4	17,0	23,6	35,6	45,5	50,0
60	0.90	-1,8	-2,1	-0,4	2,7	6,0	6,6
	0.75	3,8	2,6	6,3	10,6	16,7	19,1
	0.50	10,0	7,8	13,8	19,5	26,8	33,1
	0.25	18,5	16,1	24,6	35,0	47,3	52,5
	0.10	26,1	23,6	32,3	48,9	64,1	70,0

Table 4. N as a function of L_{EX} and exposure time. N is the sum of the N-values at the six frequencies 500, 1000, 2000, 3000, 4000 and 6000 Hz.

L_{ex} in dB(A)		Exposure time in years 2	10	20	30	40
80	90	0	1,3	1,8	2,0	2,1
	75	0,5	1,8	2,1	2,3	2,5
	50	1	2,2	2,4	2,6	2,8
	25	1,3	2,7	2,9	3,2	3,4
	10	1,6	3,1	3,5	3,8	4,0
	sum	4,4	11,1	12,8	13,9	14,8
85	90	0	6	10	11	11
	75	3	9	12	12	14
	50	6	12	14	14	18
	25	8	15	18	19	21
	10	10	17	21	23	24
	sum	27,5	59	75	79	88
90	90	0	14	22	26	30
	75	7	21	28	32	36
	50	14	28	35	39	43
	25	23	37	46	50	54
	10	31	46	56	61	64
	sum	75	146	187	207	227
95	90	0	27	44	53	60
	75	14	41	54	67	73
	50	28.5	57	70	81	86
	25	44	72	87	101	109
	10	60	93	112	122	131
	sum	146,5	293	374	424	459

Table 7. Hearing threshold levels of painters.

Mean age in years	Fractile	Frequency in hertz 500	1000	2000	3000	4000	6000
20	0.90	-4,9	-2,9	-2,6	-2,6	0,3	1,6
	0.75	-1,0	-0,7	-0,6	1,8	4,1	5,4
	0.50	3,3	1,8	1,8	6,7	8,2	9,6
	0.25	10,1	5,8	7,0	13,9	19,6	21,0
	0.10	16,1	9,5	11,8	20,3	29,9	31,4
30	0,90	-4,6	-2,9	-2,4	-2,1	0,5	2,2
	0.75	-0,6	-0,4	0,1	2,9	5,4	7,0
	0.50	3,8	2,5	3,0	8,5	10,9	12,3
	0.25	10,7	7,2	9,0	16,7	23,1	24,4
	0.10	16,9	11,4	14,4	24,0	34,0	35,3
40	0.90	-3,7	-2,9	-1,9	-0,9	0.9	6,7
	0.75	0,5	0,4	1,9	5,5	8,7	10,9
	0.50	5,2	4,1	6,1	12,7	17,3	19,0
	0.25	12,2	10,5	13,9	23,5	31,4	32,6
	0.10	18,6	16,2	20,6	33,2	44,2	44,8
50	0.90	-2,4	-2,8	-1,1	1,0	1,6	6,0
	0,75	2,2	1,7	4,7	9,7	13,9	17,1
	0.50	7,4	6,7	11,1	19,5	27,5	29,6
	0.25	14,7	15,7	21,6	34,3	44,7	45,5
	0.10	21,3	23,9	31,1	47,7	60,2	59,9
60	0.90	-0,5	-2,8	-0,0	3,6	2,5	9,1
	0.75	4,6	3,4	8,4	15,5	21,0	25,7
	0.50	10,3	10,2	17,9	28,7	41,5	44,1
	0.25	18,1	22,9	32,3	49,1	62,9	63,2
	0.10	25,1	34,3	45,1	67,5	82,2	80,5

Table 8. Difference between hearing threshold levels of painters and of the B.I.-reference group.

Mean age in years	Fractile	Frequency in hertz 500	1000	2000	3000	4000	6000
20	0.90	0,3	2,7	3,3	1,6	4,1	5,5
	0.75	1,2	2,7	2,7	3,2	4,1	4,2
	0.50	2,1	2,8	1,9	4,9	4,2	2,8
	0.25	4,1	2,2	2,4	3,9	7,3	6,0
	0.10	5,9	1,7	2,8	3,0	10,1	8,8
30	0.90	0,4	2,4	3,1	1,6	3,5	5,2
	0.75	1,1	2,6	2,6	3,3	4,1	4,4
	0.50	2,0	2,8	2,1	5,2	4,9	3,5
	0.25	3,7	2,6	2,8	4,7	7,9	6,4
	0.10	5,3	2,4	3,4	4,2	10,7	9,0
40	0.90	0,5	1,8	2,5	1,4	2,0	4,7
	0.75	1,0	2,2	2,5	3,6	4,2	4,9
	0.50	1,6	2,7	2,5	6,1	6,5	5,1
	0.25	2,9	3,4	3,8	6,7	9,5	7,3
	0.10	4,0	4,1	4,7	7,2	12,3	9,3
50	0.90	0,8	0,8	1,6	1,2	-0,3	3,8
	0.75	1,0	1,6	2,3	4,1	4,2	5,6
	0.50	1,1	2,6	3,2	7,4	9,2	7,5
	0.25	1,5	4,9	5,4	9,8	12,1	8,7
	0.10	1,9	6,9	7,5	12,0	14,7	9,8
60	0.90	1,2	-0,6	0,3	0,9	-3,4	2,6
	0.75	0,8	0,8	2,1	4,9	4,3	6,5
	0.50	0,3	2,4	4,1	9,3	12,8	10,9
	0.25	-0,4	6,8	7,6	14,2	15,6	10,7
	0.10	-1,0	10,7	10,9	18,6	18,1	10,5

Table 11. Differences between hearing threshold levels of painters and of the German data base of "Malern und Lackierern (M + L)".

Age in years	Fractile	Frequency in hertz 500	1000	2000	3000	4000	6000
20	0,90	-2	2	2	0	-3	+4
	0,50	-4	-4	-5	-1	1	-2
	0,10	-3	-8	-7	0	8	4
30	0,90	-2	0	1	-3	0	1
	0,50	-5	-4	-4	-2	0	-2
	0,10	-7	-8	-5	-1	6	0
40	0,90	-2	-1	-2	-3	-1	0
	0,50	-4	-3	-3	0	1	1
	0,10	-1	-3	-1	4	7	5
50	0,90	0	0	1	-1	-2	0
	0,50	-2	-1	1	1	8	6
	0,10	-3	4	2	-1	7	4
60	0,90	0	-2	-5	-8	-12	-7
	0,50	-3	-4	2	-1	4	-1
	0,10	-5	1	-9	-1	0	-5

Table 12. Differences between hearing threshold levels of painters and of the "M + L"-data base, assumming that the difference of the median value is zero at an age of 20 years.

Age in years	Fractile	Frequency in hertz 500	1000	2000	3000	4000	6000
20	0,90	2	6	7	1	-4	6
	0,50	0	0	0	0	0	0
	0,10	1	-2	-2	1	7	6
30	0,90	2	4	6	-2	-1	3
	0,50	-1	0	1	-1	-1	0
	0,10	-3	-4	0	0	5	2
40	0,90	2	3	3	-2	-2	2
	0,50	0	1	2	1	0	3
	0,10	3	1	4	5	6	7
50	0,90	4	4	6	0	-3	2
	0,50	2	3	6	2	7	8
	0,10	1	0	7	0	6	6
60	0,90	4	2	0	-7	-13	-5
	0,50	1	0	7	0	3	1
	0,10	-1	5	-4	0	-1	-3

Table 13. Differences between the hearing threshold levels of otologically unscreened industrial workers with L_{EX}-values of less than 80 dB(A) and the TNO reference group (upper part) and differences in hearing threshold levels of these workers, unscreened and screened with respect to occupational noise exposure in previous jobs (lower part).

Frequency in hertz	Differences with TNO reference group		
	$\Delta H_{0,90}$	$\Delta H_{0,50}$	$\Delta H_{0,10}$
500	0,4	2,0	4,7
1000	0,2	0,7	2,9
2000	0,0	0,8	3,2
500, 1000, 2000	0,2	1,2	3,6
3000	0,3	1,0	8,1
4000	1,2	2,8	6,8
6000	4,3	5,2	9,2
3000, 4000, 6000	1,9	3,0	8,0
	Differences due to selection of previous occupational noise exposure		
500, 1000, 2000	1,1	1,1	0,6
3000, 4000, 6000	2,3	4,2	8,0

Table 14. Differences between hearing threshold levels of painters and of the B.I.-reference group, for a mean age of 40 years.

Frequency in hertz	$\Delta\ H_{0,90}$	$\Delta\ H_{0,50}$	$\Delta\ H_{0,10}$
500	0,5	1,6	4,0
1000	1,8	2,7	4,1
2000	2,5	2,5	4,7
3000	1,4	6,1	7,2
4000	2,0	6,5	12,3
6000	4,7	5,1	9,3

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1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12

Age class in years	Number of persons
< 21	7
21-25	26
26-30	38
31-35	69
36-40	98
41-45	63
46-50	67
51-55	45
56-60	32

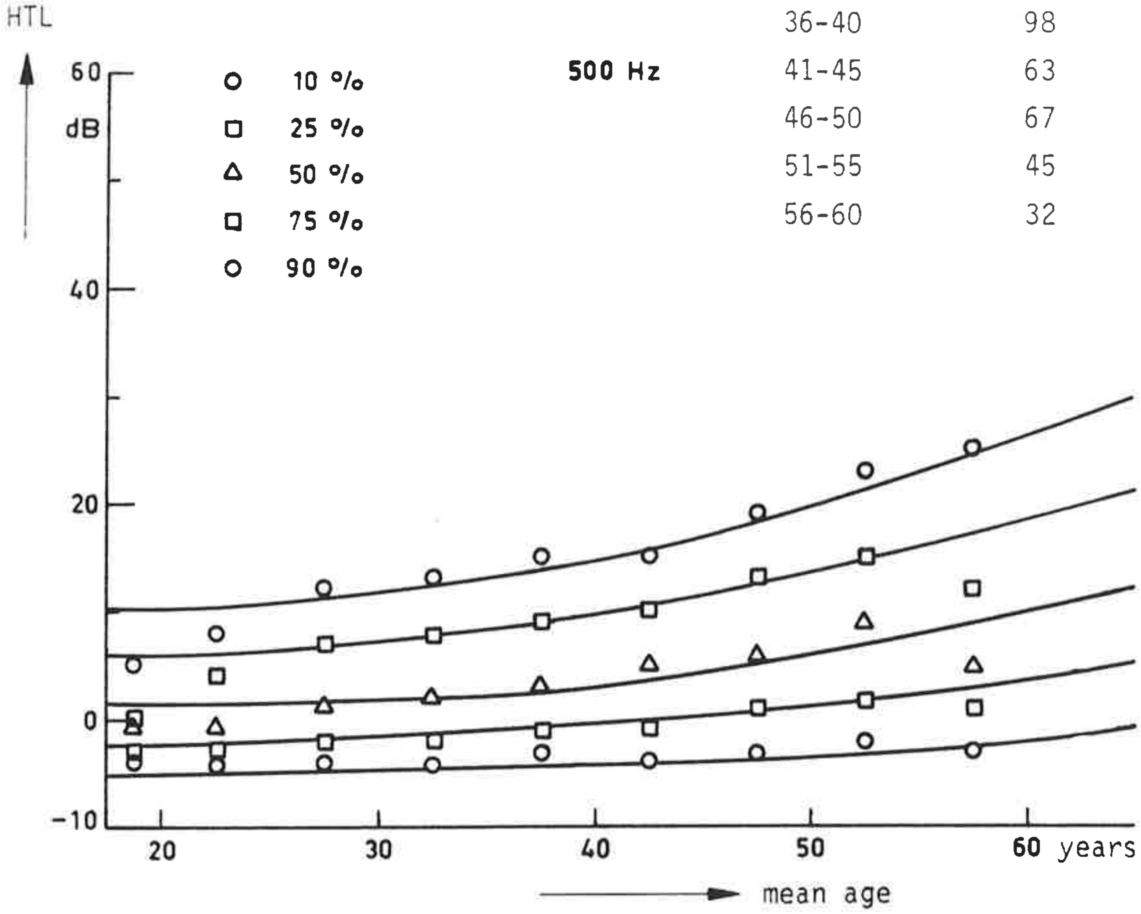


Figure 1

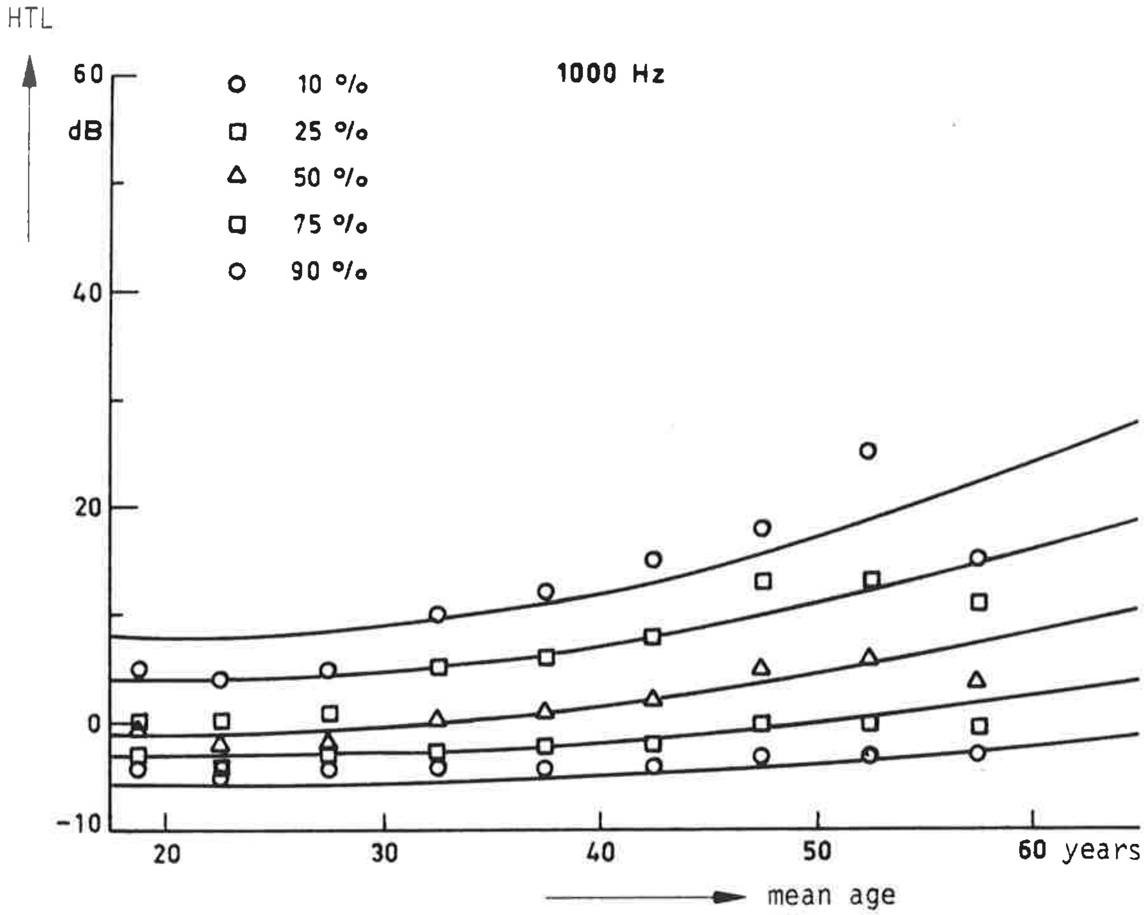

HTL
60
dB
40
20
0
-10
10 %
25 %
50 %
75 %
90 %
1000 Hz
20
30
40
50
60 years
mean age

Figure 2

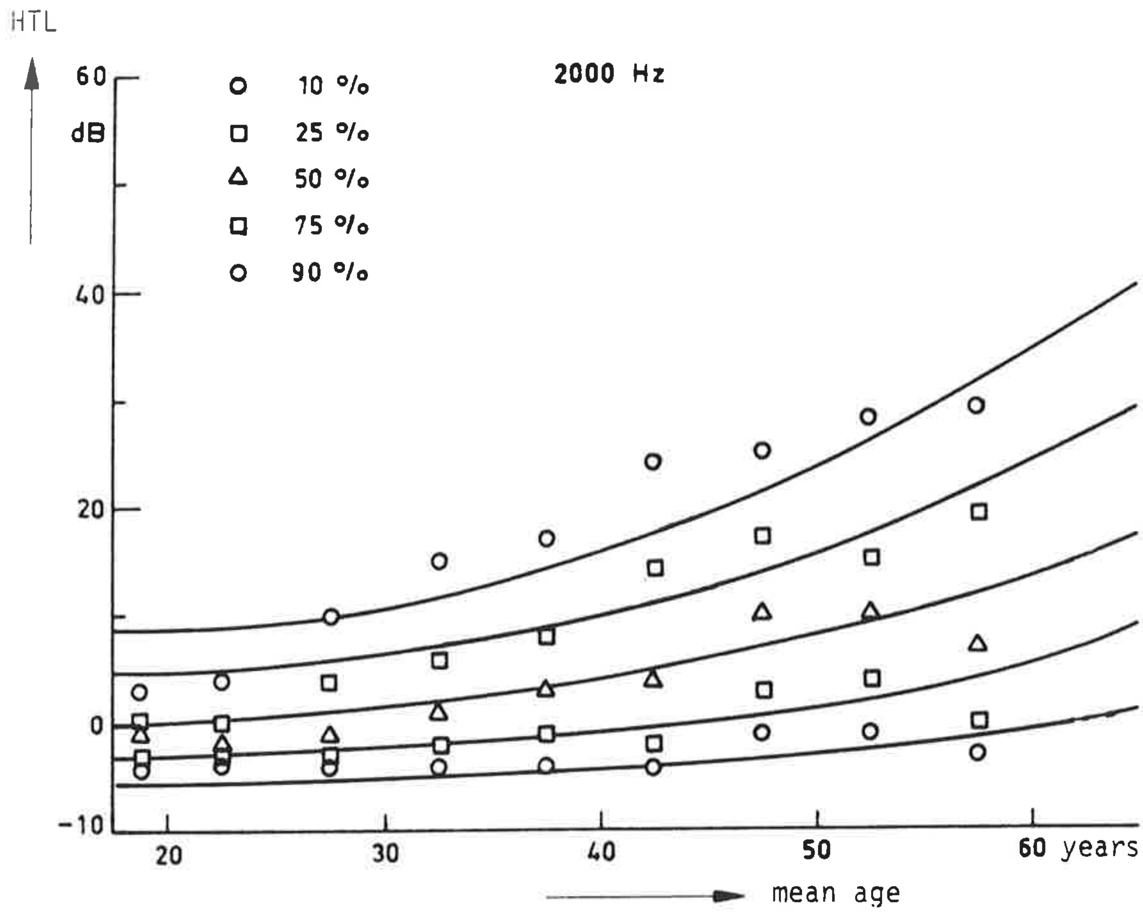

HTL
60
dB
40
20
0
-10
10 %
25 %
50 %
75 %
90 %
2000 Hz
20
30
40
50
60 years
mean age

Figure 3

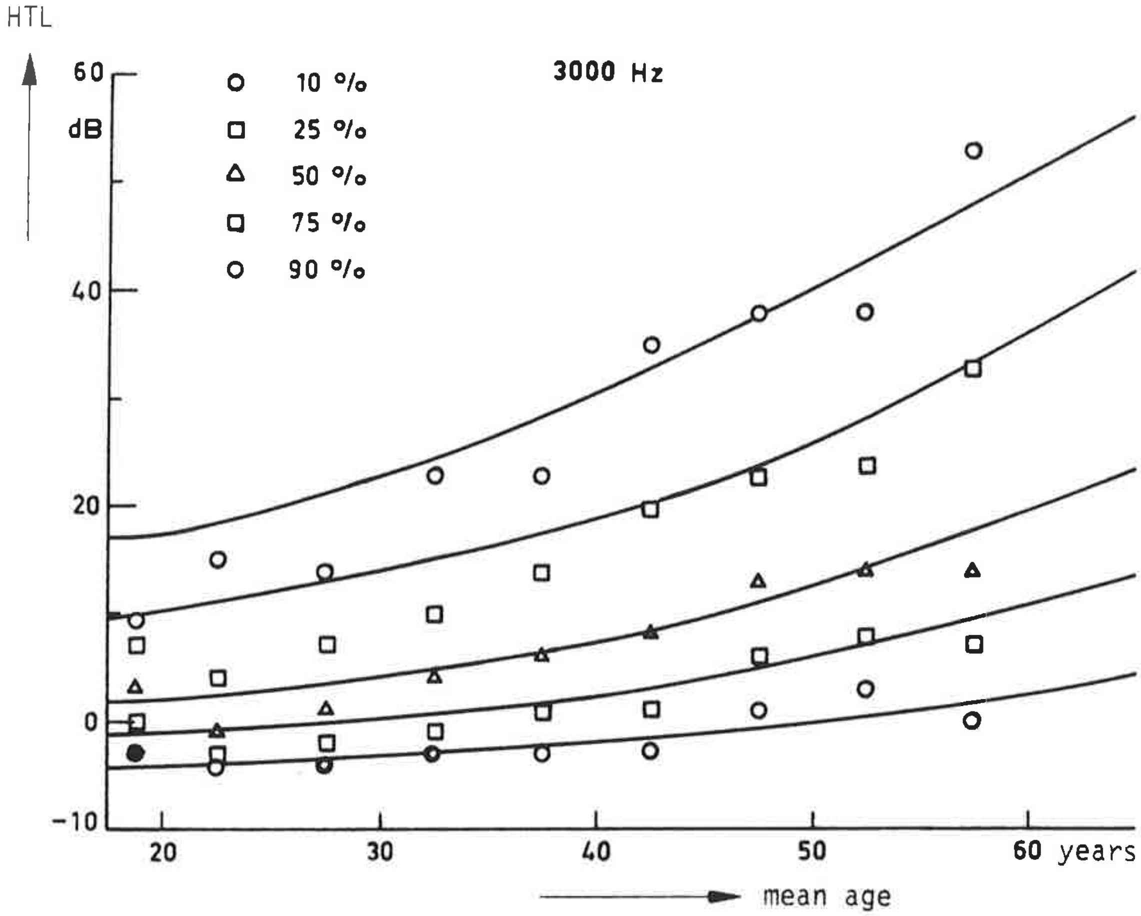

HTL
60
dB
40
20
0
-10
10 %
25 %
50 %
75 %
90 %
3000 Hz
20
30
40
50
60 years
mean age

Figure 4

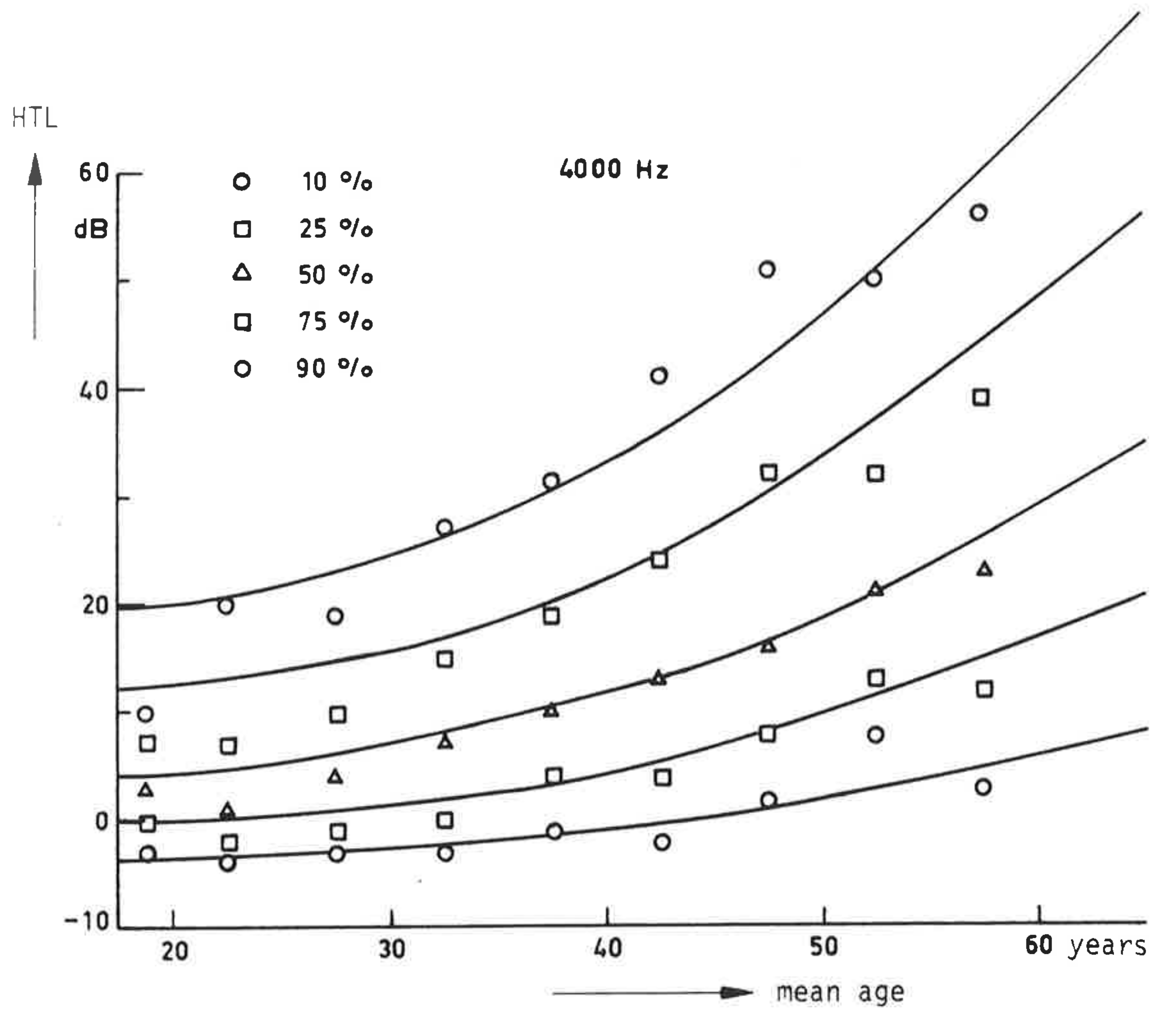

HTL
60
dB
40
20
0
-10
10 %
25 %
50 %
75 %
90 %
4000 Hz
20
30
40
50
60 years
mean age

Figure 5

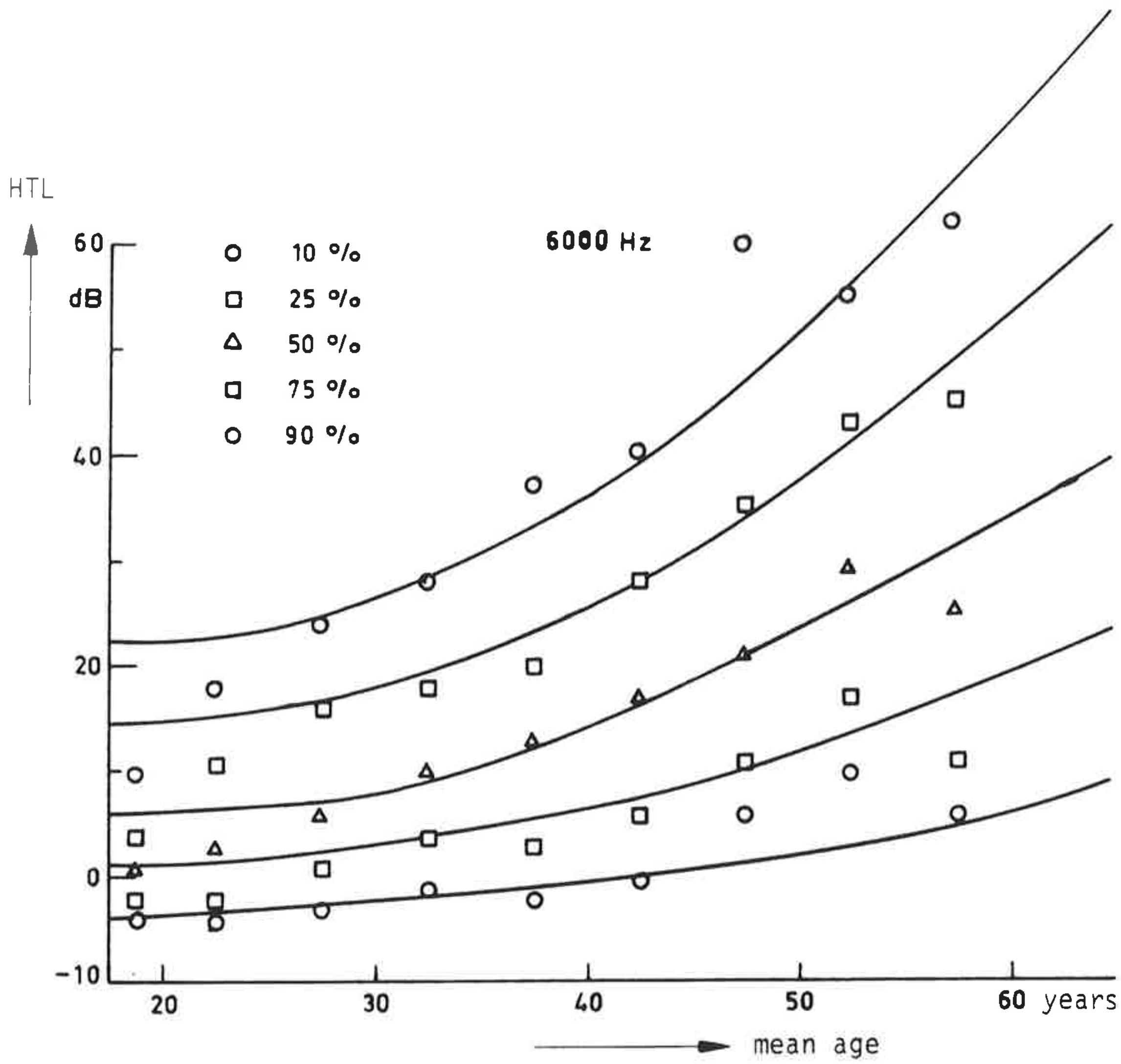

HTL
60
dB
40
20
0
-10
10 %
25 %
50 %
75 %
90 %
6000 Hz
20
30
40
50
60 years
mean age

Figure 6

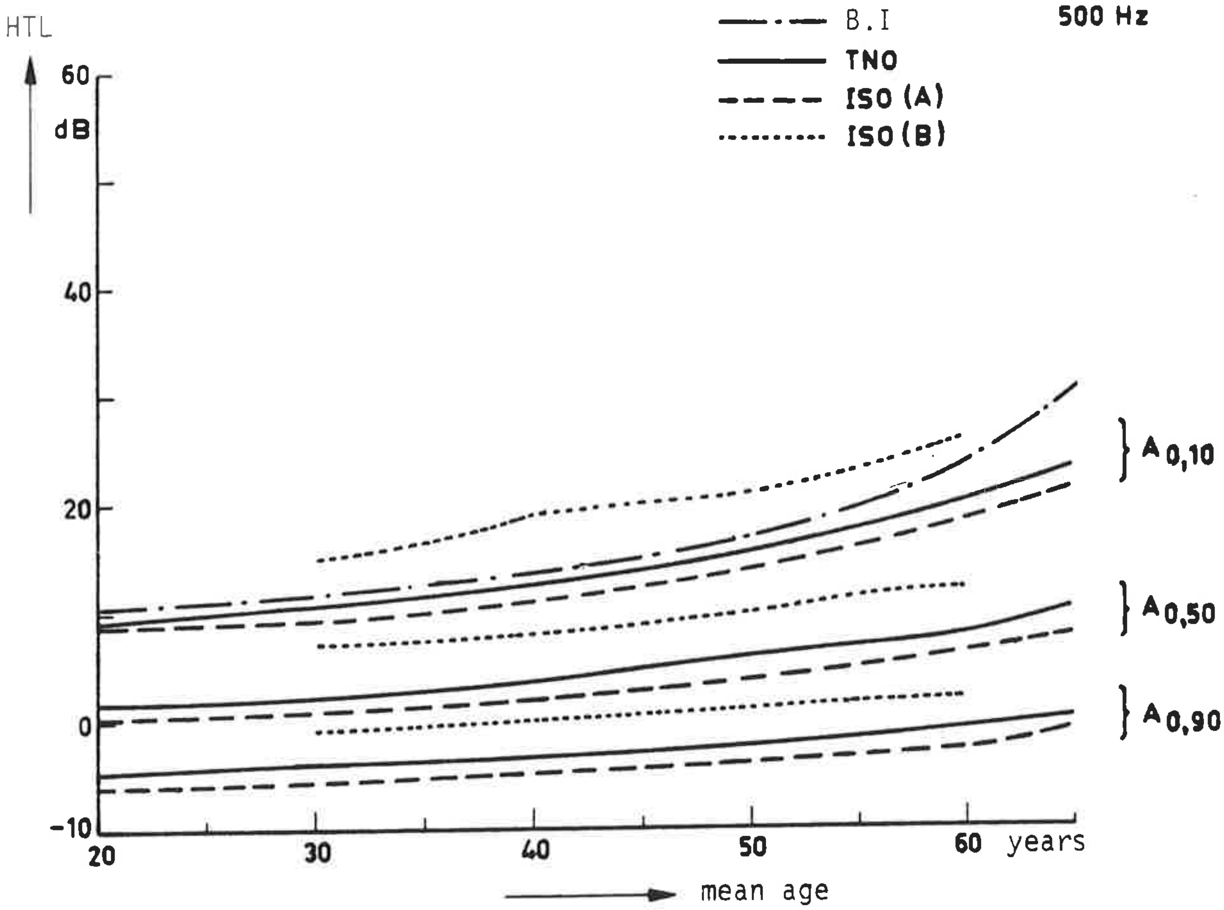
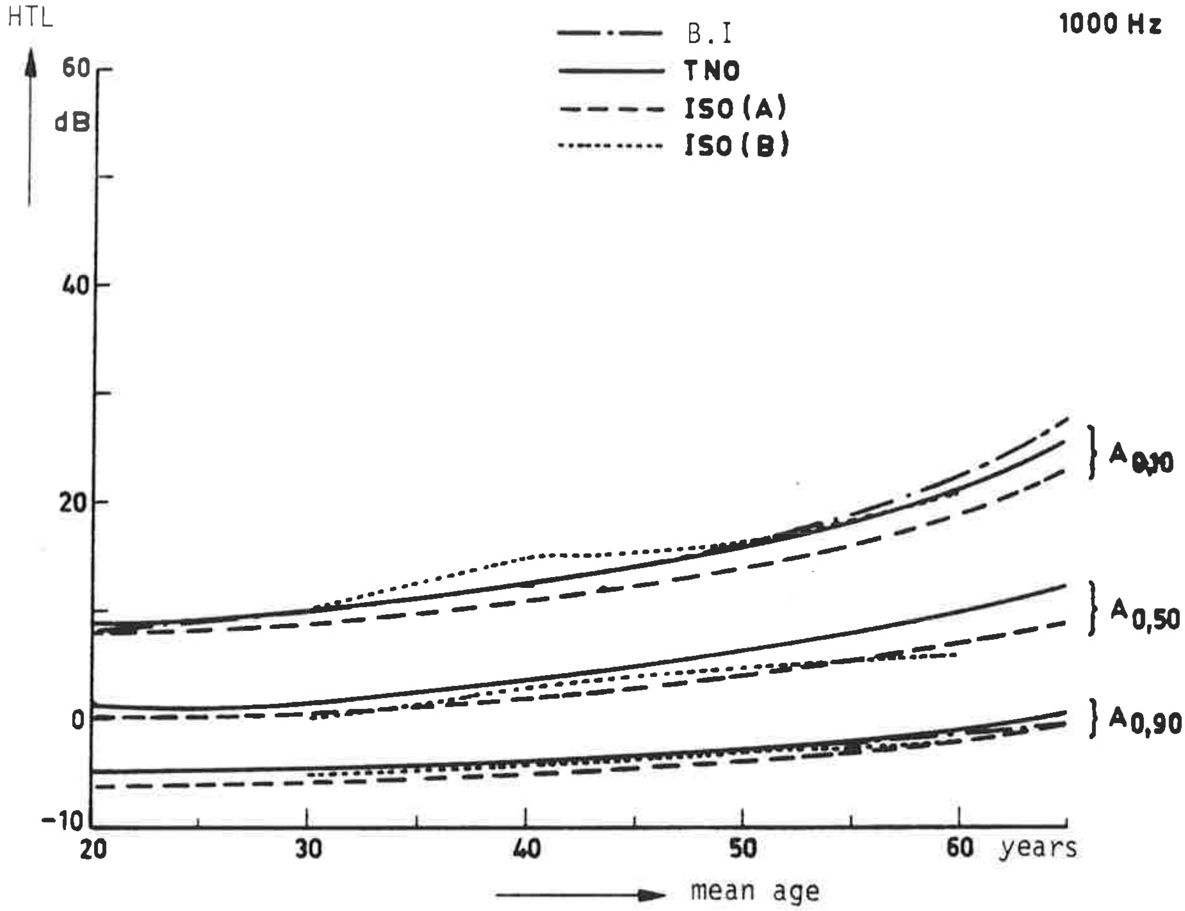

HTL
60
dB
40
20
0
-10
20
30
40
50
60 years
mean age
B.I
TNO
ISO (A)
ISO (B)
500 Hz
A0,10
A0,50
A0,90

Figure 7



HTL
60
dB
40
20
0
-10
B.I
TNO
ISO (A)
ISO (B)
1000 Hz
A0,10
A0,50
A0,90
20
30
40
50
60
years
mean age

Figure 8

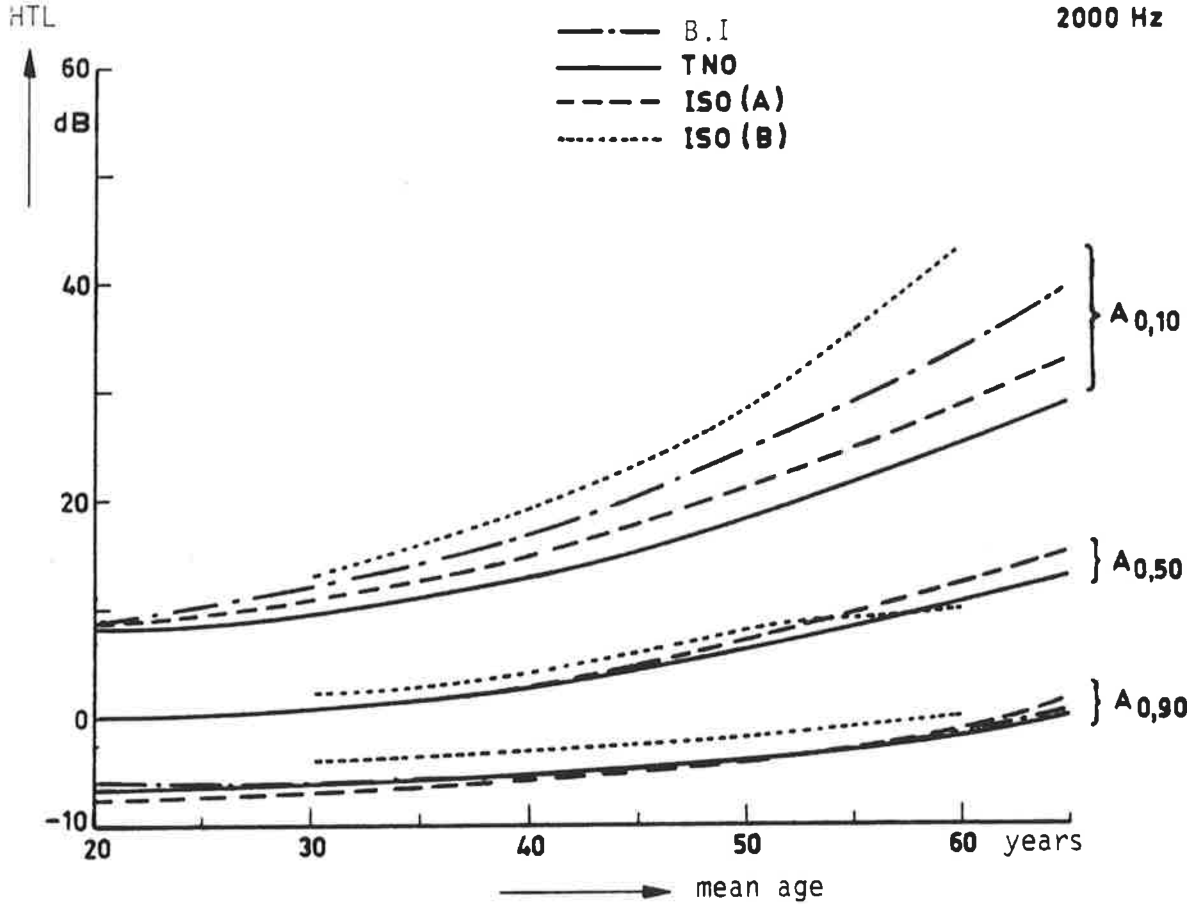

HTL
60
dB
40
20
0
-10
20
30
40
50
60
years
mean age
B.I
TNO
ISO (A)
ISO (B)
2000 Hz
$A_{0,10}$
$A_{0,50}$
$A_{0,90}$

Figure 9

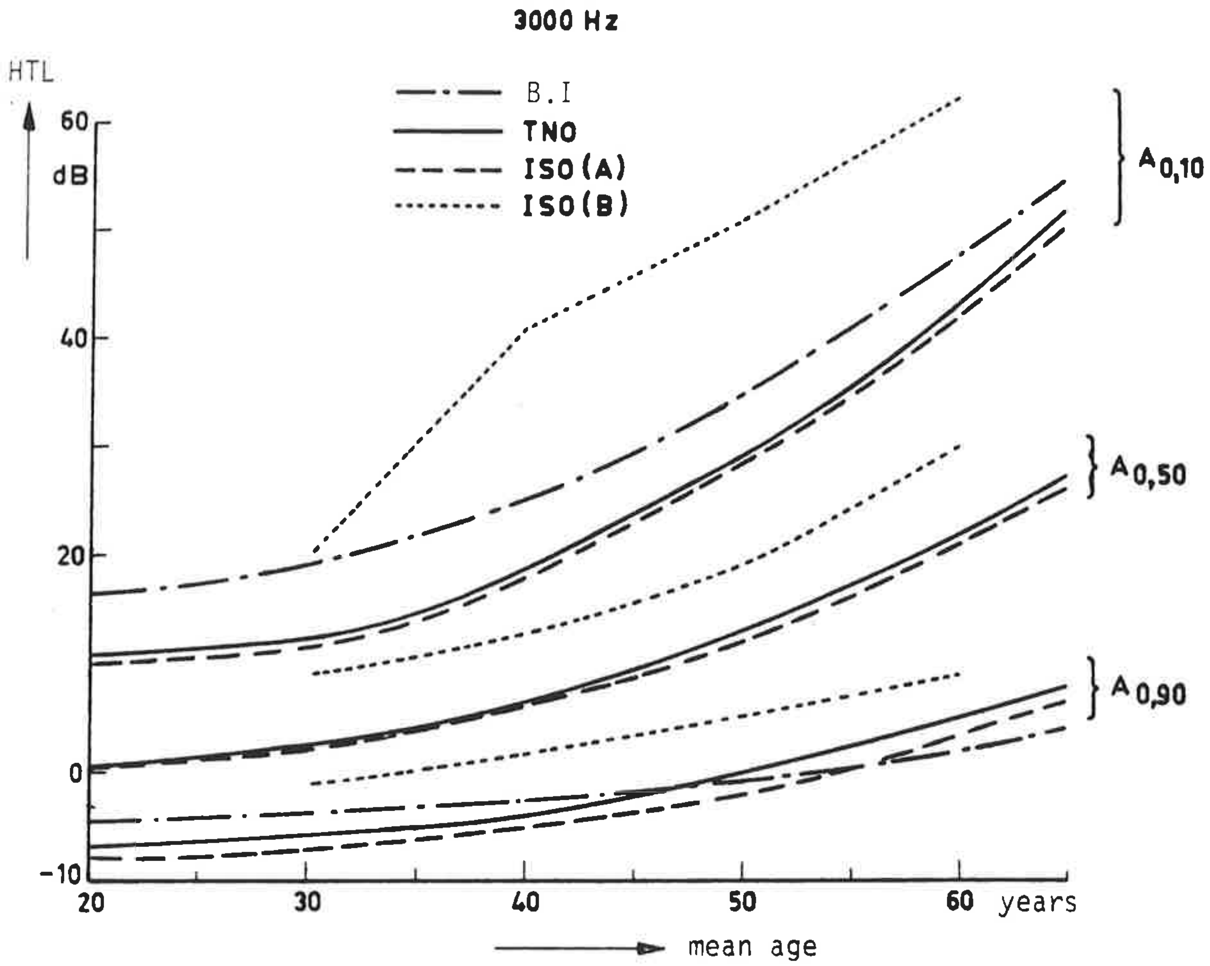

3000 Hz
HTL
dB
B.I
TNO
ISO(A)
ISO(B)
$A_{0,10}$
$A_{0,50}$
$A_{0,90}$
60
40
20
0
-10
20
30
40
50
60
years
mean age

Figure 10

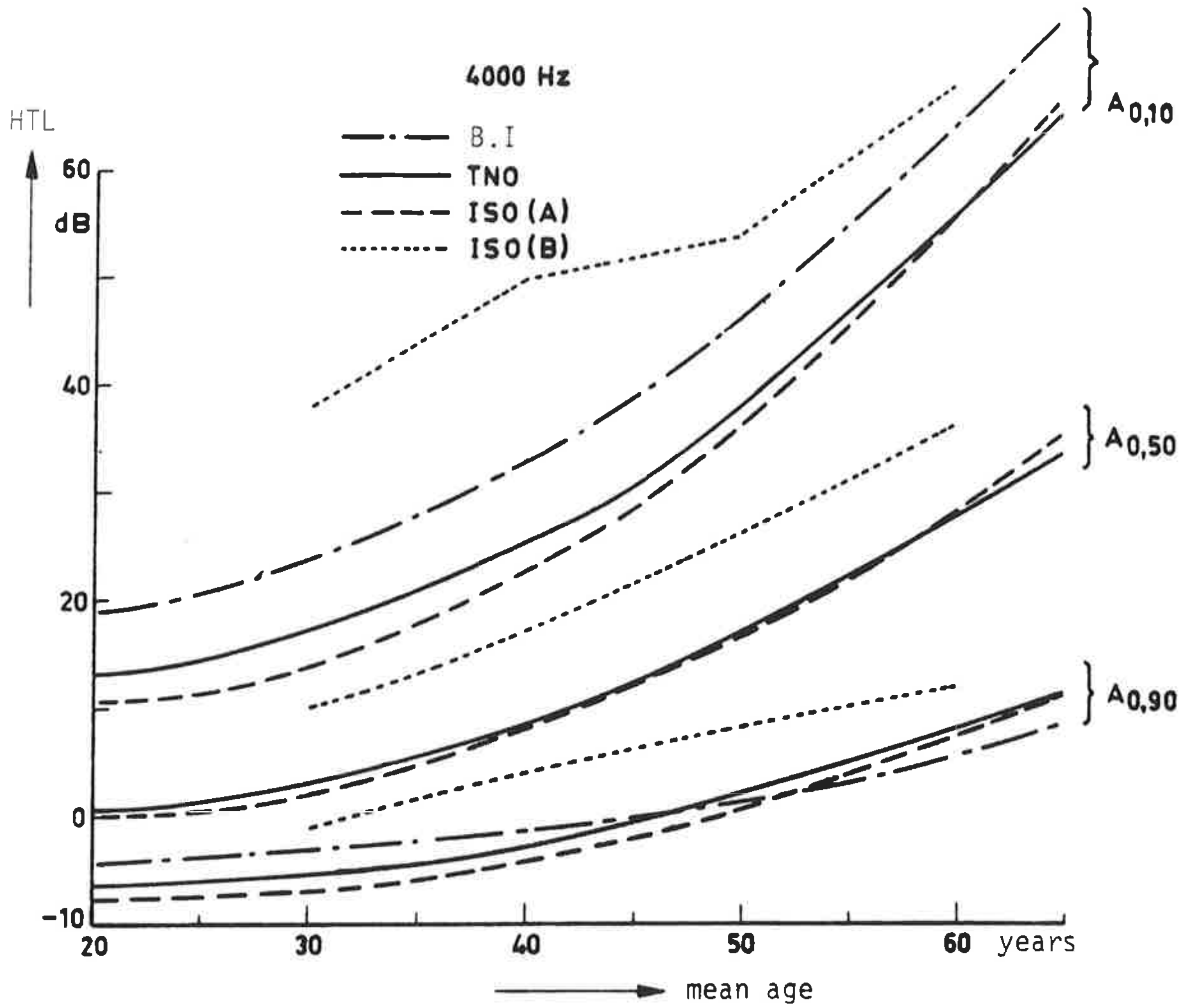

4000 Hz
HTL
60
dB
40
20
0
-10
B.I
TNO
ISO (A)
ISO (B)
A0,10
A0,50
A0,90
20
30
40
50
60
years
mean age

Figure 11

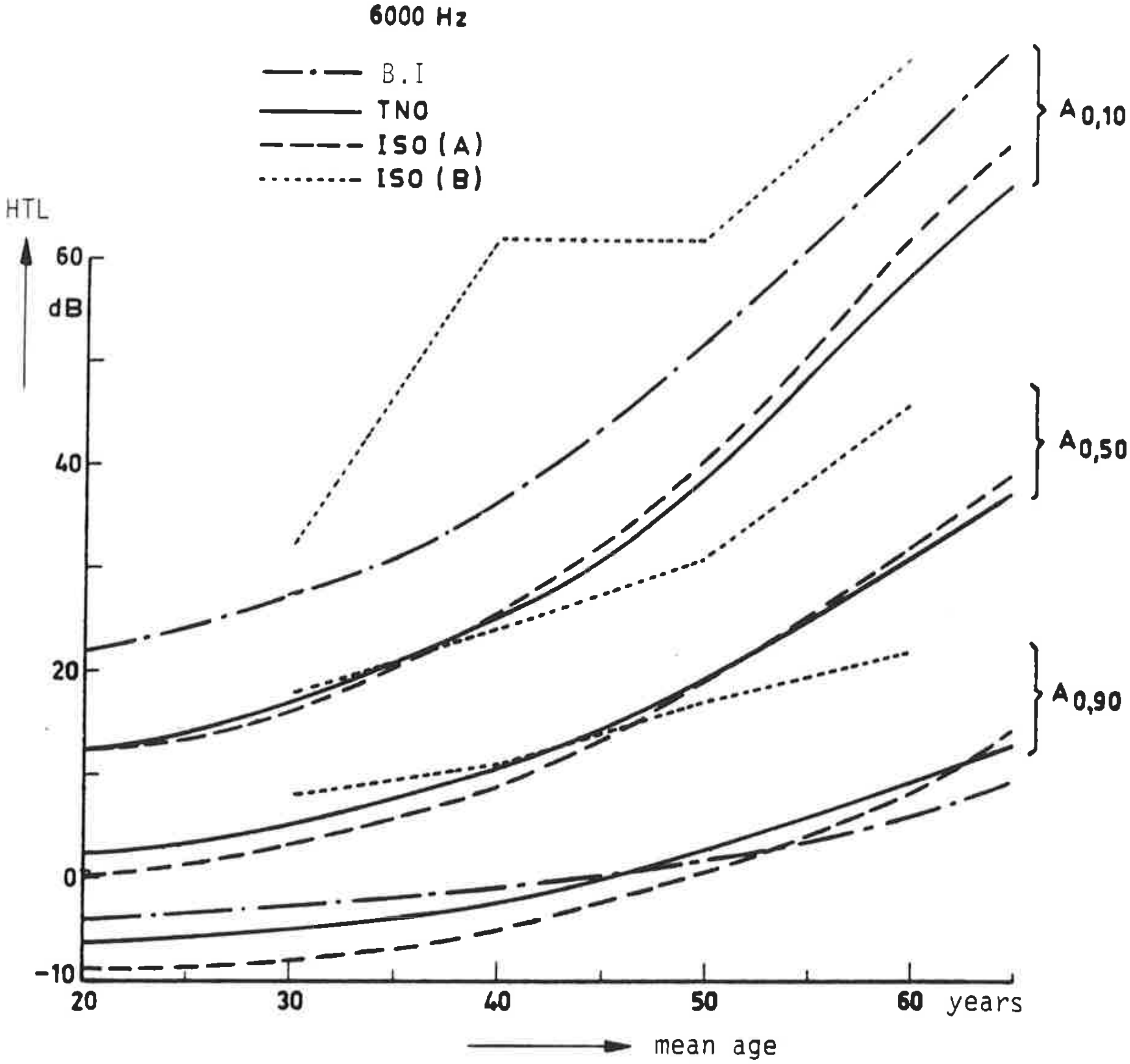

6000 Hz
B.I
TNO
ISO (A)
ISO (B)
HTL
dB
60
40
20
0
-10
20
30
40
50
60
years
mean age
$A_{0,10}$
$A_{0,50}$
$A_{0,90}$

Figure 12