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hearing loss

due to exposure to steady-state broadband noise

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CONTENTS

SUMMARY

Report 35 [1] determines the influence of steady-state broadband noise on the hearing levels of people exposed to noise for eight hours a day, five days a week. The said report is limited to the hearing levels not exceeded in 75, 50 and 25% of the people. The present Supplement to Report 35 examines in which way the hearing levels not exceeded in 90% and 10% of the people can be estimated from the 75, 50 and 25%-values. In this context it analyses 26 group audiograms from the Report "Een inventarisatie van geluidspectra en afdelingsaudiogrammen in de Nederlandse industrie (Sound spectra and group audiograms in the Dutch industry)" published by the Organisation for Health Research TNO, 1963.

Our statistical analysis of these group audiograms showed that:

1. the hearing levels above the median hearing level up to the 90%-value are distributed according to a normal distribution at 500, 1000, 2000, 3000, 4000 and 6000 Hz. At 8000 Hz the real 90%-value is generally larger than the one estimated from a normal distribution.
2. the hearing levels below the median hearing level down to the 10%-value are distributed normally at 500, 3000, 4000 and 6000 Hz. At 1000, 2000 and 8000 Hz the real 10%-value is on the average somewhat larger than would be estimated from a normal distribution. However, the percentage of people which exceeds in fact the estimated 10%-value is about 8 to 9 percent, so that in practice one can use the normal distribution.
3. The difference between the hearing level not exceeded in 90% of the people and the median hearing level is, in a good approximation, independent of median hearing level and of exposure time, at least for exposure times of more than 10 years.
4. The difference between the hearing level not exceeded in 10% of the people and the median hearing level is, also in a good approximation independent of exposure time, for exposure times of at least 10 years, and independent of the median hearing level.

For exposure times of at least 10 years, the difference between the 90%-value and the median hearing level, as well as the difference between the 10%-value and the median hearing level, were calculated as a function of the NR 500 to 2000 Hz of the noise.

I. INTRODUCTION

Report 35 determines the influence of steady-state broadband noise on the hearing levels of people exposed to noise for eight hours a day, at least five days a week. That report is limited to the hearing levels, not exceeded in 75%, 50% and 25% of the people exposed to noise. In its Introduction, Report 35 points out that the work was mainly done to get the data, that are necessary to establish a limit of "safe" noise. Although the report does give important information about the damage caused by noise, we should not extrapolate its results to a limit of safe noise. To do this, we have to be informed about the hearing levels which are less favourable than the 75%-values, e.g. about the hearing levels not exceeded in 90% of the people.

The pertinent literature gives hardly any data on the hearing levels not exceeded in more than 75% of the people exposed to noise. However, we have a large number of audiograms from [2]. Each of these group audiograms gives for a group of people, working in noise, the hearing levels not exceeded in 90%, 75%, 50%, 25% and 10% of the people as a function of frequency. An example is given in Figure 1. Unfortunately, it is impossible to determine in a systematic way from these audiograms the relation between noise and the hearing level not exceeded in 90% of the people since exact data on noise, age and exposure time are only known for a too limited number of groups.

According to certain criteria, indicated below, a number of groups audiograms from the said publication have been selected. From these groups audiograms, we examined in which way the hearing levels not exceeded in 90% and 10% of the people can be derived from those not exceeded in 75%, 50% and 25% of the people. Fortunately, Report 35 already gives the 75%-, 50%-, and 25%-values as a function of several variables, such as: mean exposure time, age and noise level. Accordingly, one can determine also the 10%- and 90%-values as a function of those variables, when one knows how the 10%- and 90%-values can be derived from the 75%-, 50%- and 25%-values.

II. DATA

We selected group audiograms from [1] according to the following criteria:

- continuous -

- continuous exposure of the group to steady-state broadband noise;
- mean exposure time of the group for at least eight years;
- a fairly low order of difference between the individual exposure times of the people of the group.

The group audiograms of 26 groups, working in noise, were thus elaborated. Table I presents some information about the number of people per group.

Table I

Number of people per group	Number of groups
10 up to 19	1
20 up to 29	9
30 up to 39	7
49 up to 49	6
70 up to 79	1
80 up to 89	1
90 up to 99	1

III. DIFFERENCES BETWEEN ESTIMATED AND REAL VALUES OF HEARING LEVELS NOT EXCEEDED IN 90% AND 10% OF THE PEOPLE EXPOSED

III.1. Mean differences

From the group audiograms at 500, 1000, 2000, 3000, 4000, 6000 and 8000 Hz, we determined the hearing levels not exceeded in 90%, 75%, 50%, 25%, and 10% of the people.

The hearing level, at a certain frequency, just not exceeded in x % of the people of a group, we indicate by: $L_{e,x\%}$.

We examined in which way $L_{e,10\%}$ and $L_{e,90\%}$ can be estimated from $L_{e,75\%}$, $L_{e,50\%}$ and $L_{e,25\%}$. We investigated the distribution of the hearing levels. From Report 35 (e.g. Figure 49) we know that $L_{e,75\%} - L_{e,50\%}$ is larger than $L_{e,50\%} - L_{e,25\%}$; this is not in accordance with a normal distribution of the hearing levels. Therefore, we tested the hypothesis that the hearing levels above the median value have a normal distribution, as well as the hearing levels below the median value, at least for the values that are limited by $L_{e,90\%}$ and $L_{e,10\%}$.

If the distribution of the hearing levels above the median hearing level is normal, then:

$$L_{e,90\%} = L_{e,75\%} + 0,93\ (L_{e,75\%} - L_{e,50\%}) \qquad (1)$$

and if the distribution is normal below the median value:

$$L_{e,10\%} = L_{e,25\%} - 0,93\ (L_{e,50\%} - L_{e,25\%}) \qquad (2)$$

Using (1) and (2), we estimated $L_{e,90\%}$ and $L_{e,10\%}$ from $L_{e,75\%}$, $L_{e,50\%}$ and $L_{e,25\%}$. At the same time the real values of $L_{e,90\%}$ and $L_{e,10\%}$ were known from the group audiograms. The difference between the estimated and real value of $L_{e,90\%}$ we indicate by: $Y_{90\%}$, and the difference between the real and estimated value of $L_{e,10\%}$ by: $Y_{10\%}$. Then:

$$Y_{90\%} = L_{e,90\%}\ (\text{estimated}) - L_{e,90\%}\ (\text{real}) \qquad (3)$$

$$Y_{10\%} = L_{e,10\%}\ (\text{estimated}) - L_{e,10\%}\ (\text{real}) \qquad (4)$$

When the hearing levels are normally distributed, $Y_{90\%}$ and $Y_{10\%}$ are equal to zero. We calculated $Y_{90\%}$ and $Y_{10\%}$ for the 26 groups at 500, 1000, 2000, 3000, 4000, 6000 and 8000 Hz, except for 3 groups at 3000 and 6000 Hz; for these 3 groups the hearing levels at 3000 and 6000 Hz are not given in the group audiograms. For each frequency, we next calculated the mean value of $Y_{90\%}$ and of $Y_{10\%}$ from the 26 or 23 group-values, as well as the standard deviation of these mean values. The results are shown in Table II. It is surprising that the mean values of $Y_{90\%}$ are positive at each frequency (except at 8000 Hz), whereas $Y_{10\%}$ is negative at each frequency. This means that the estimated value of $L_{e,90\%}$ is somewhat larger than the real value, and the estimated value of $L_{e,10\%}$ is somewhat smaller than the real value.

The last four columns of Table II given the results of the testing of the hypothesis that $Y_{90\%}$ and $Y_{10\%}$ do not differ from zero significantly (5%-level), or, in other words, that the distribution of the hearing levels above and below the median value are normal. From the very last column it will be seen that for $Y_{90\%}$ the hypothesis can be accepted at each frequency, except at 8000 Hz, whereas for $Y_{10\%}$ the hypothesis can be accepted only for 500, 3000, 4000 and 6000 Hz and should be rejected for 1000, 2000 and 8000 Hz.

Table II

Frequency	Mean value of $Y_{90\%}$	Standard deviation	t*	γ*	P*	Hypothesis
500 Hz	0.88 dB	0.71 dB	1.123	25	0.2-0.4	acc.
1000	0.21	0.78	0.269	25	0.8	acc.
2000	0.15	0.87	0.172	25	0.8	acc.
3000	1.50	1.06	1.41	22	0.1-0.2	acc.
4000	1.14	0.92	1.23	25	0.2-0.4	acc.
6000	0.11	1.15	0.096	22	0.8	acc.
8000	-4.70	1.52	3.09	25	0.01	rej.
Frequency	Mean value of $Y_{10\%}$	Standard deviation	t*	γ*	P*	Hypothesis
500 Hz	-1.00 dB	0.66 dB	1.52	25	0.1-0.2	acc.
1000	-1.52	0.28	5.47	25	0.01	rej.
2000	-1.70	0.68	2.50	25	0.02	rej.
3000	-0.95	0.94	1.00	22	0.2-0.4	acc.
4000	-1.24	0.94	1.32	25	0.2	acc.
6000	-1.43	0.98	1.46	22	0.1-0.2	acc.
8000	-3.50	1.00	3.50	25	0.01	rej.

* t: ratio of the mean value of $Y_{90\%}$ or $Y_{10\%}$ to the standard deviation

γ: number of degrees of freedom

P: probability that a value of t as large as the obtained value, or larger, could occur on the basis of chance variations in sampling.

The results of this paragraph will be considered more closely in Chapter IV.

- III.2. -

III.2. Differences between estimated and real values of hearing levels, not exceeded in 90% and 10% of the people, versus median hearing levels

From the results given in the previous paragraph one might conclude that $Y_{90\%}$ is not significantly different from zero, so that the hearing levels above the median value are normally distributed. However, before applying this conclusion rashly, one should realise that so far we had examined data of groups which differed very much in exposure time, age and noise level. It might be possible for instance, that $Y_{90\%}$ depends on one of these factors. Unfortunately, all these factors are known for a too limited number of groups. Fortunately we do know the $L_{e,50\%}$ of each group and this quantity is closely related to the factors mentioned. Therefore, we next examined whether $Y_{90\%}$ and $Y_{10\%}$ depend upon $L_{e,50\%}$.

In Figures 2...15, $Y_{90\%}$ and $Y_{10\%}$ are plotted as a function of $L_{e,50\%}$. In each Figure, the best-fitting straight line has been drawn; these straights have been calculated according to the method of least squares. The equations of the straight lines are shown in Table III. In its last three columns, the hypothesis is tested that $Y_{90\%}$ and $Y_{10\%}$ are independent of $L_{e,50\%}$. It turns out that the slope of all straight lines do not differ from zero significantly (5% - level). Therefore, we can accept the hypothesis as valid in each case considered.

Frequency	Table III Best fitting straight line ($x = L_{e,50\%}$)	Standard deviation slope	t_{slope}	Hypothesis
500 Hz	$Y_{90\%} = -0.09\,x + 1.6$	0.099	0.91	acc.
1000	$Y_{90\%} = 0.07\,x - 0.4$	0.067	0.98	acc.
2000	$Y_{90\%} = 0.01\,x - 0.6$	0.053	0.19	acc.
3000	$Y_{90\%} = 0.12\,x + 4.3$	0.096	1.25	acc.
4000	$Y_{90\%} = 0.04\,x - 0.1$	0.047	0.76	acc.
6000	$Y_{90\%} = -0.11\,x + 2.8$	0.069	1.59	acc.
8000	$Y_{90\%} = 0.12\,x - 1.5$	0.078	1.54	acc.

Frequency	Best fitting straight line ($x = L_{e,50\%}$)	Standard deviation slope	t_{slope}	Hypothesis
500 Hz	$Y_{10\%} = -0.10\ x - 0.2$	0.087	1.14	acc.
1000	$Y_{10\%} = -0.09\ x - 0.6$	0.044	2.02	acc.
2000	$Y_{10\%} = -0.05\ x - 0.8$	0.041	1.17	acc.
3000	$Y_{10\%} = 0.01\ x - 0.9$	0.089	0.12	acc.
4000	$Y_{10\%} = 0.02\ x - 1.8$	0.049	0.32	acc.
6000	$Y_{10\%} = 0.003x - 1.5$	0.065	0.04	acc.
8000	$Y_{10\%} = -0.06\ x - 2.0$	0.050	1.04	acc.

IV. APPLICATION OF FINDINGS PRESENTED IN CHAPTER III ON THE DATA OF REPORT 35

In the work described in Chapter III we found that $Y_{90\%}$ does not differ significantly from zero, except at 8000 Hz. However, the best estimate of $Y_{90\%}$ at a certain frequency is the value given in Table II. Therefore, in the following we will examine what differences are obtained when either zero or the value from Table II is used for $Y_{90\%}$. To that end, we compare the following two distributions of the hearing levels:

(1) $L_{e,50\%}$, $L_{e,75\%}$, $L_{e,90\%}$ (estimated) [$Y_{90\%} = 0$]

(2) $L_{e,50\%}$, $L_{e,75\%}$, $L_{e,90\%}$ (real) [$Y_{90\%}$ = value from Table II]

According to (1), the percentage of people which does not exceed $L_{e,90\%}$ (estimated) is 90%. From the second distribution we can also determine the percentage of people which does not exceed $L_{e,90\%}$ (estimated) (see Figure 16). This percentage will be somewhat larger than 90%, because $Y_{90\%}$ is positive at each frequency (except at 8000 Hz). Table IV gives the results when for $L_{e,75\%}$ and $L_{e,50\%}$ we use the values given in Figure 49 of Report 35. Similar operations were carried out for the 10% - values.

- Table IV -

Table IV

Frequency	Percentage which does not exceed $L_{e,90\%}$ (estimated)	Percentage which does not exceed $L_{e,10\%}$ (estimated)
500 Hz	91.5 %	8.0 %
1000	90.5	8.0
2000	90.0	8.5
3000	91.5	9.0
4000	91.5	8.5
6000	90.0	8.5
8000	86.0	4.0

Table IV shows that the estimated percentage which does not exceed $L_{e,90\%}$ (estimated), that is 90%, and the real percentage which does not exceed $L_{e,90\%}$ (estimated) differ by about 1%, except at 8000 Hz. In practice, these differences are of no importance. Therefore, we will take $Y_{90\%}$ to be zero in our calculations, and we will estimate $L_{e,90\%}$ from $L_{e,75\%}$ and $L_{e,50\%}$ according to a normal distribution. We will take $Y_{10\%}$ to be zero,too.

However, there is another effect which we have to take into account when we derive $L_{e,90\%}$ from $L_{e,75\%}$ and $L_{e,50\%}$ given in Report 35. In Chapter IV.1. of Report 35 we showed that $L_{e,75\%} - L_{e,50\%}$ is independent of exposure time T, although the slopes of the best fitting straight lines of $L_{e,75\%} - L_{e,50\%}$ against T are unequal to zero. As $L_{e,75\%} - L_{e,50\%}$ is not significantly dependent on T, the mean value of $L_{e,75\%} - L_{e,50\%}$ is used in Report 35. When next we calculate, furthermore, $L_{e,90\%}$, or $L_{e,90\%} - L_{e,50\%}$, assuming that $Y_{90\%}$ is independent of $L_{e,50\%}$, we apply in fact two simplifications:

(a) $L_{e,75\%} - L_{e,50\%}$ is independent of T

(b) $Y_{90\%}$ ($L_{e,90\%}$ (estimated) - $L_{e,90\%}$ (real) is independent of $L_{e,50\%}$ (and therefore of T, because $L_{e,50\%}$ and T are very closely related).

This may be clear from the following formula:

$$L_{e,90\%}\text{ (real)} - L_{e,50\%} = 1.93\,(L_{e,75\%} - L_{e,50\%}) - Y_{90\%} \quad (5)$$

- Analogously -

Analogously for $L_{e,10\%}$ (real):

$$L_{e,50\%} - L_{e,10\%} \text{ (real)} = 1.93\ (L_{e,50\%} - L_{e,25\%}) + Y_{10\%} \qquad (6)$$

Although $L_{e,75\%} - L_{e,50\%}$ as well as $Y_{90\%}$ are not significantly dependent on T, it is quite possible that both effects strenhten each other, so that the real value of $L_{e,90\%} - L_{e,50\%}$ depends on T. Therefore, we will now examine whether $L_{e,90\%}$ (real) $- L_{e,50\%}$ depends on T. At the same time we will consider $L_{e,50\%} - L_{e,10\%}$(real) as a function of T.

Putting for "change per year" we rewrite formulae (5) and (6):

$$\Delta(L_{e,90\%} \text{ (real)} - L_{e,50\%}) = 1.93\ \Delta(L_{e,75\%} - L_{e,50\%}) - \Delta Y_{90\%}$$

$$\Delta(L_{e,50\%} - L_{e,10\%} \text{ (real)} = 1.93\ \Delta(L_{e,50\%} - L_{e,25\%}) + \Delta Y_{10\%}$$

$\Delta(L_{e,75\%} - L_{e,50\%})$ and $\Delta(L_{e,50\%} - L_{e,25\%})$ are given in Report 35 (page 13) for several NR's for 500 to 2000 Hz. $\Delta Y_{90\%}$ and $\Delta Y_{10\%}$ are calculated from Table III in this Supplement, with the assumption that the best-fitting straight lines of Table III ($Y_{90\%}$ and $Y_{10\%}$ against $L_{e,50\%}$) are applicable for each NR for 500 to 2000 Hz. To be able to use the data from Table III, we first calculated the increase of $L_{e,50\%}$ for several NR's for 500 to 2000 Hz from the data of Report 35. The increase of $L_{e,50\%}$ was calculated over a period of 30 years, the exposure time increasing from 10 to 40 years and age from 30 to 60 years.
From the increase of $L_{e,50\%}$ we calculated the change of $Y_{90\%}$ and that of $Y_{10\%}$ for several NR's for 500 to 2000 Hz from Table III. From these values, we next calculated the mean change per year of $Y_{90\%}$ and $Y_{10\%}$.

In Table V, the results are shown for NR 75 and NR 98. The values for the intermediate NR's for 500 to 2000 Hz were found to lie between these values.

- Table V -

Table V

Frequency	Change of $L_{e,90\%}$ (real) - $L_{e,50\%}$		Change of $L_{e,50\%} - L_{e,10\%}$ (real)	
	NR 75	NR 98	NR 75	NR 98
500 Hz	0.14 dB/year	0.16 dB/year	-0.08 dB/year	-0.08 dB/year
1000	0.24	0.20	-0.02	-0.05
2000	-0.05	-0.07	+0.16	+0.10
3000	-0.13	-0.11	-0.05	-0.04
4000	-0.17	-0.18	-0.16	-0.15
6000	-0.27	-0.22	+0.20	+0.20
8000	0.22	0.27	+0.01	+0.00

Table V shows the change per year of $L_{e,90\%}$ (real) - $L_{e,50\%}$, and that of $L_{e,50\%} - L_{e,10\%}$ (real). When we accept that $L_{e,75\%} - L_{e,50\%}$ and $L_{e,50\%} - L_{e,25\%}$, as well as $Y_{90\%}$ and $Y_{10\%}$, are independent of T and then calculate the mean values of $L_{e,90\%} - L_{e,50\%}$ and $L_{e,50\%} - L_{e,10\%}$, the differences between these values and $L_{e,90\%}$ (real) - $L_{e,50\%}$ or $L_{e,50\%} - L_{e,10\%}$ (real) are 15 times the values given in Table V for the shortest exposure times (10 years) and the longest exposure times (40 years). They vary with NR and frequency from -4 to +4 dB. Just as in the first part of this chapter, we converted a difference between real hearing level and estimated hearing level (here the time averaged value) into a difference of the percentages of people that do not exceed these hearing levels. These difference-percentages vary from -4 to 4%. These percentages are so small, that we feel safe in taking the line that $L_{e,90\%} - L_{e,50\%}$ and $L_{e,10\%}$ are independent of exposure time.

In Table VI and Figure 17 $L_{e,90\%} - L_{e,50\%}$ and $L_{e,50\%} - L_{e,10\%}$ are given as a function of NR for 500 to 2000 Hz, for exposure times of at least 10 years. $L_{e,90\%} - L_{e,10\%}$ and $L_{e,50\%} - L_{e,10\%}$ have been calculated from Figure 49 of Report 35, using these formulas:

$$L_{e,90\%} - L_{e,50\%} = 1.93\ (L_{e,75\%} - L_{e,50\%})$$

$$L_{e,50\%} - L_{e,10\%} = 1.93\ (L_{e,75\%} - L_{e,50\%})$$

- Table VI -

NR for 500 to 2000 Hz	$L_{e,90\%} - L_{e,50\%}$						
	500 Hz	1000 Hz	2000 Hz	3000 Hz	4000 Hz	6000 Hz	8000 Hz
75	9.5	9.5	10.5	11.5	25.0	15.5	15.5
80	9.5	9.5	14.5	15.5	24	19.5	19.5
85	9.5	9.5	15.5	21.5	23.5	21.5	21
90	9.5	9.5	17.5	26	21.5	24	23
94	9.5	9.5	20.5	26	19.5	25.5	23
98	9.5	10.5	25	26	14.5	27	23

NR for 500 to 2000 Hz	$L_{e,50\%} - L_{e,10\%}$						
	500 Hz	1000 Hz	2000 Hz	3000 Hz	4000 Hz	6000 Hz	8000 Hz
75	7.5	7.5	6	17.5	25	17.5	11.5
80	7.5	7.5	6	17.5	25	22	13.5
85	7.5	7.5	10.5	20	24.5	27	14
90	7.5	7.5	15.5	22	23	29	14.5
94	9	9	18	22.5	19	30.5	15
98	10.5	10.5	19	22.5	17.5	31	16

VI. CONCLUSIONS

In this Supplement to Report 35 it was shown that:

(1) $L_{e,90\%}$ can be derived from $L_{e,75\%}$ and $L_{e,50\%}$ under the assumption of a normal distribution of the hearing levels above the median value;

(2) $L_{e,10\%}$ can be derived from $L_{e,50\%}$ and $L_{e,25\%}$ under the assumption of a normal distribution of the hearing levels below the median value,

while, at the same time,

(3) $L_{e,90\%} - L_{e,50\%}$ is, in a good approximation, independent of $L_{e,50\%}$ and of exposure time for exposure times of at least 10 years.

(4) $L_{e,50\%} - L_{e,10\%}$ is, in a good approximation, independent of $L_{e,50\%}$ and of exposure time for exposure times of at least 10 years.

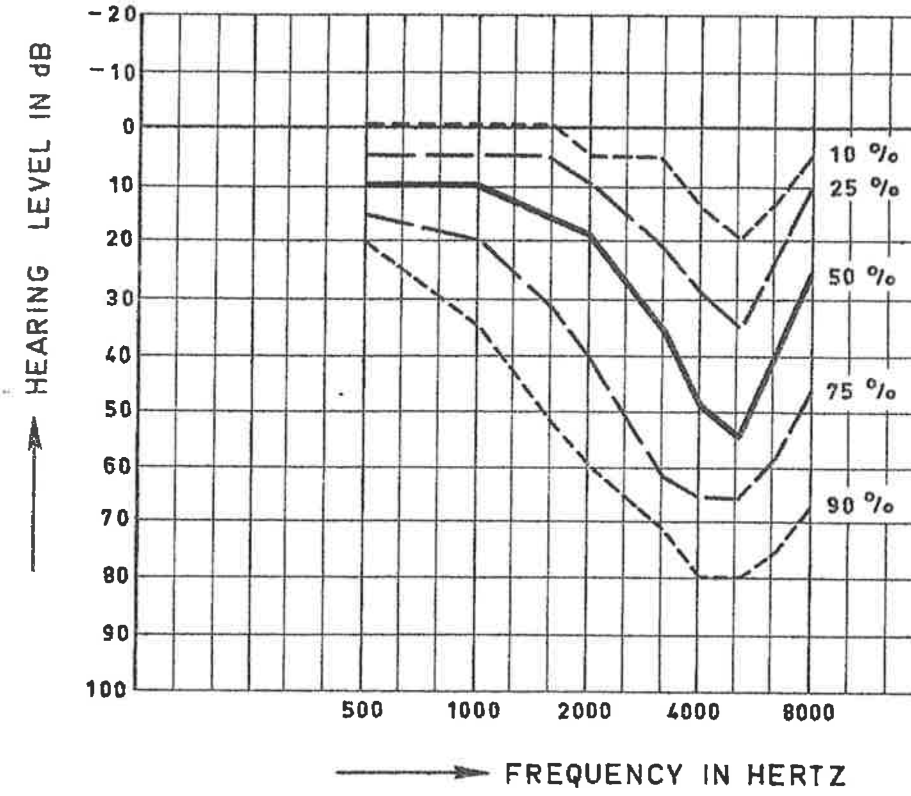
- References -

References

[1] Hearing loss due to exposure to steady-state broadband noise. Mrs. W. Passchier-Vermeer. Institute for Public Health Engineering TNO, P.O. Box 214, Delft, Netherlands.

[2] Een inventarisatie van geluidspectra en afdelingsaudiogrammen in de Nederlandse industrie (sound spectra and group audiograms in the Dutch industry). This Report is obtainable from G. Ragay, Organization for Health Research TNO, P.O. Box 297, The Hague, Netherlands.

WEAVERS



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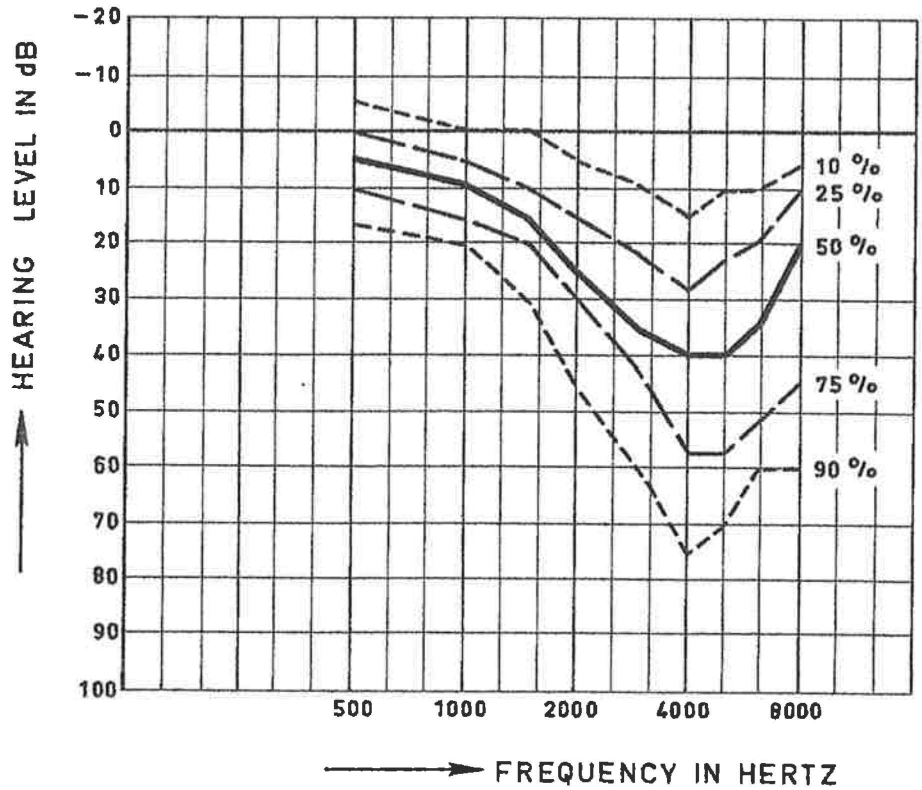

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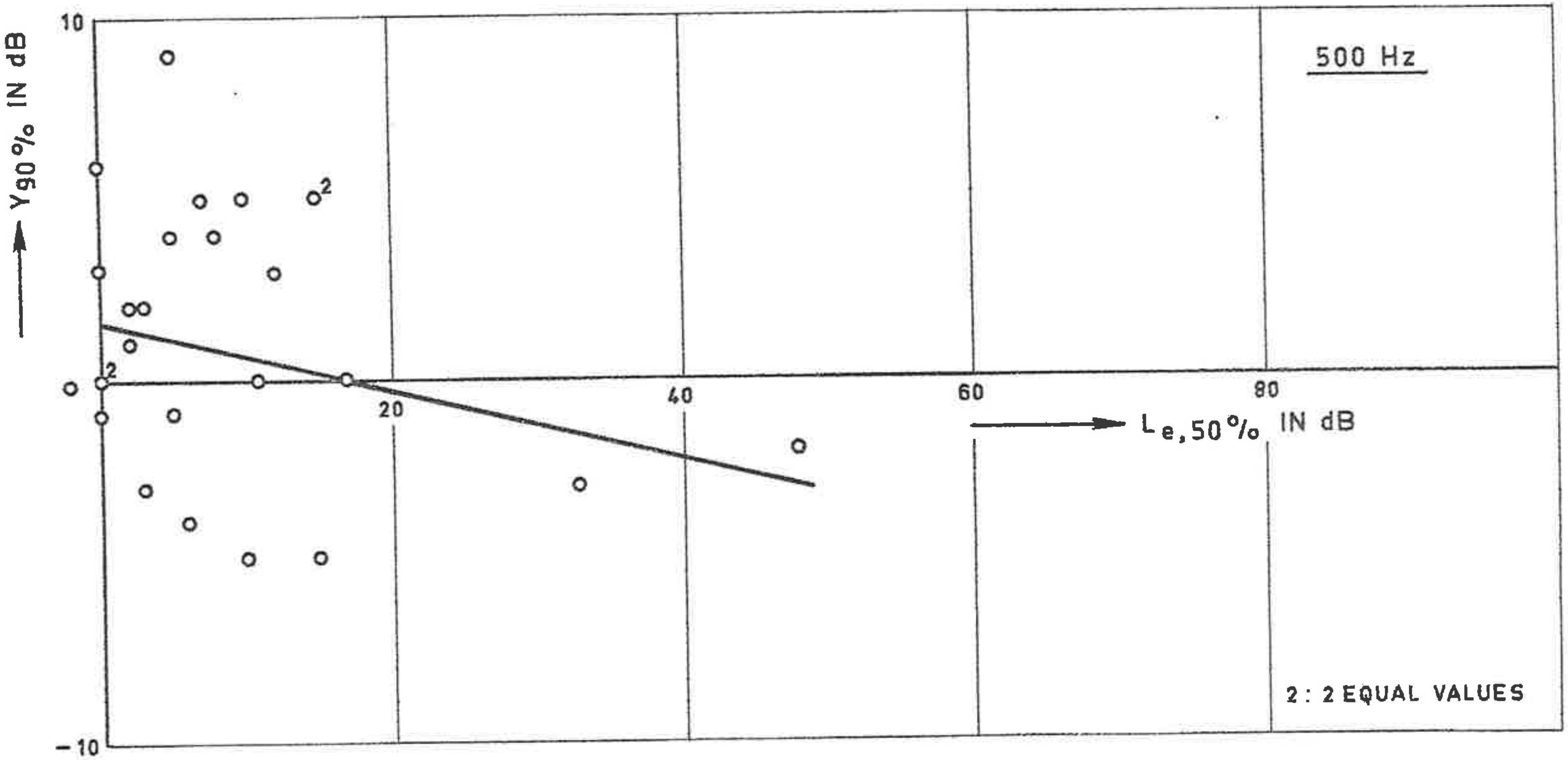
IG-TNO AFD. GELUID EN LICHT

R35 (S) - 2

DIFFERENCE ($Y_{90\%}$) BETWEEN $L_{e,90\%}$ (ESTIMATED) AND $L_{e,90\%}$ (REAL) AS A FUNCTION OF $L_{e,50\%}$



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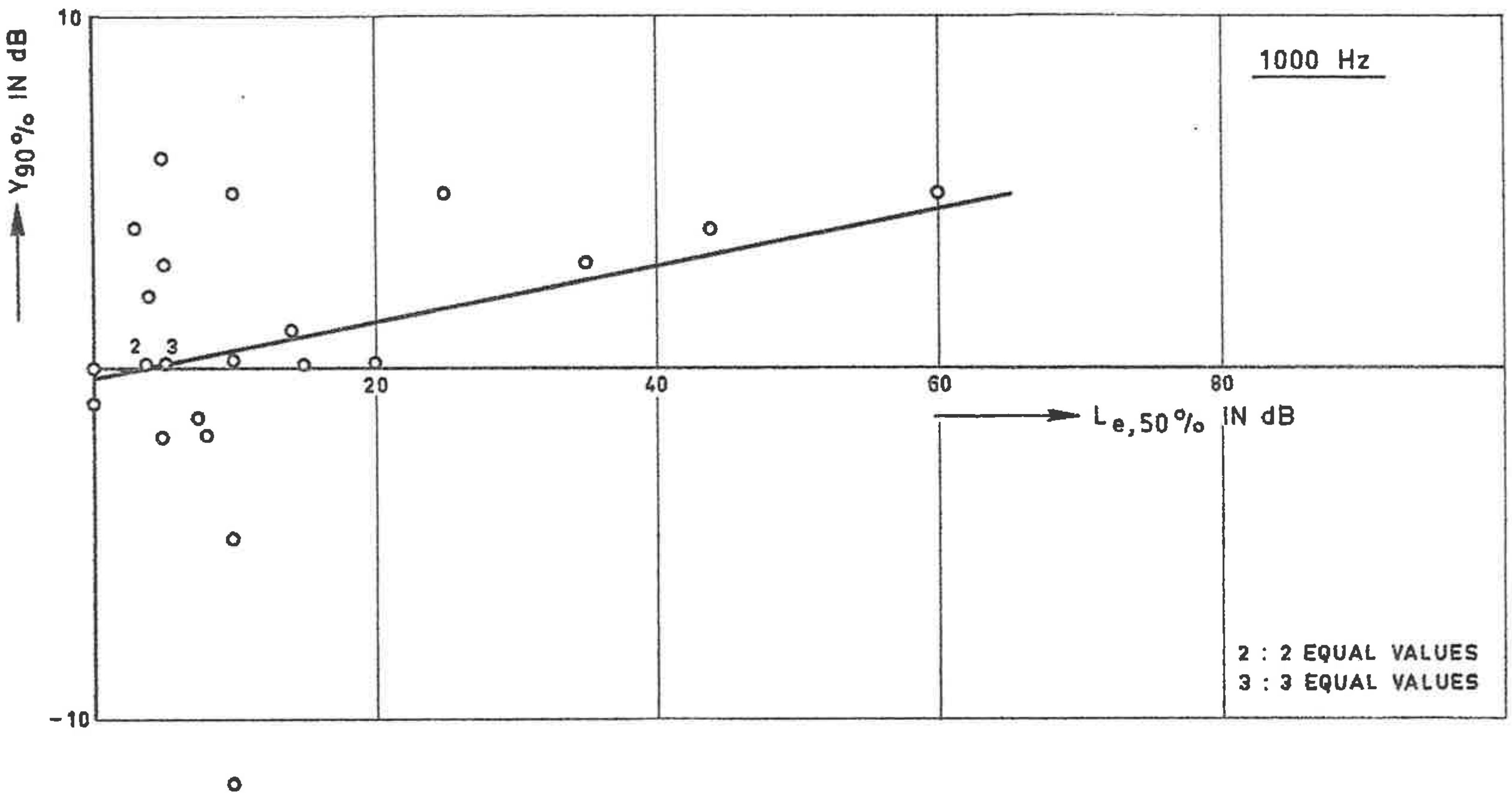

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IG-TNO AFD. GELUID EN LICHT

R35(S)-4

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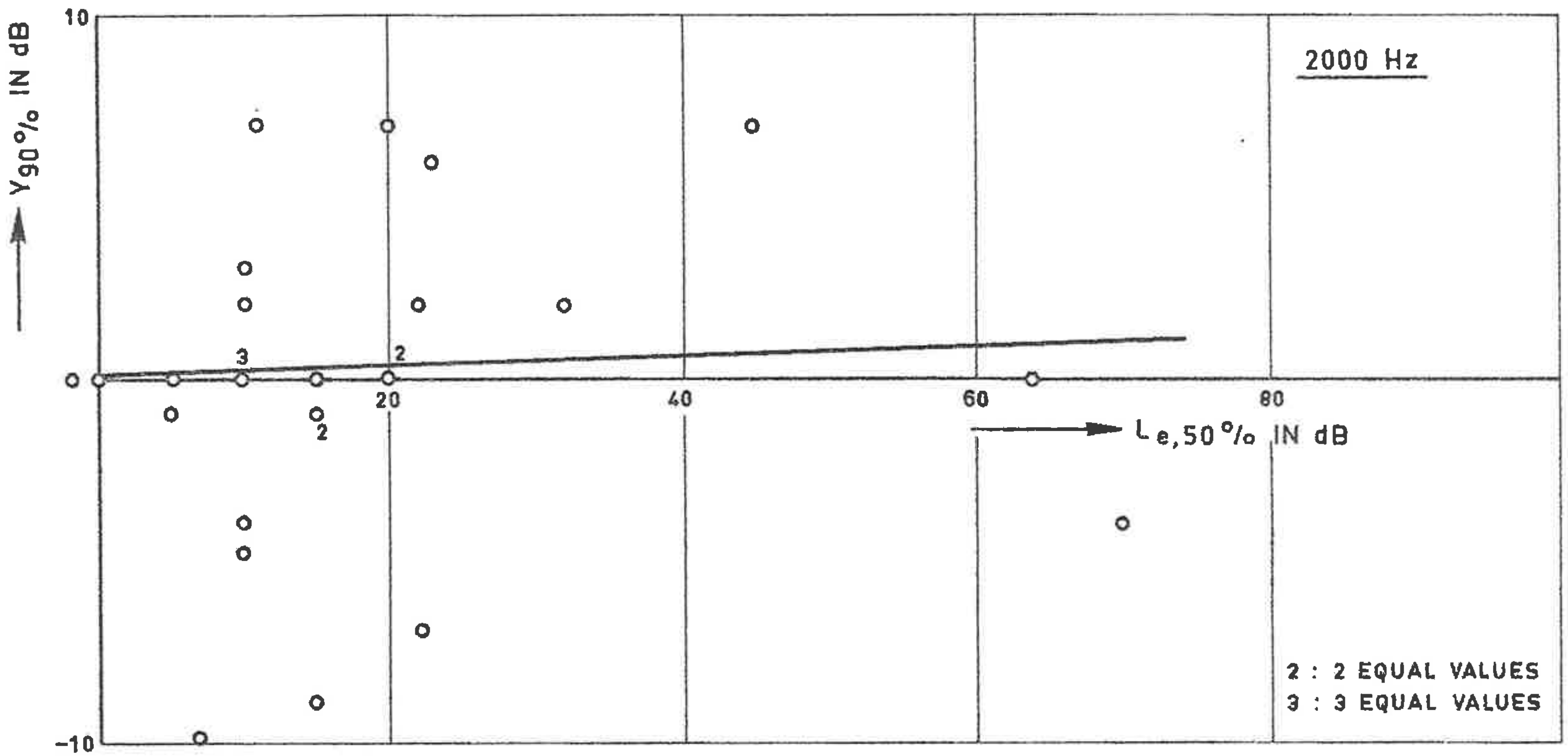

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IG-TNO AFD. GELUID EN LICHT

R35(S)-5

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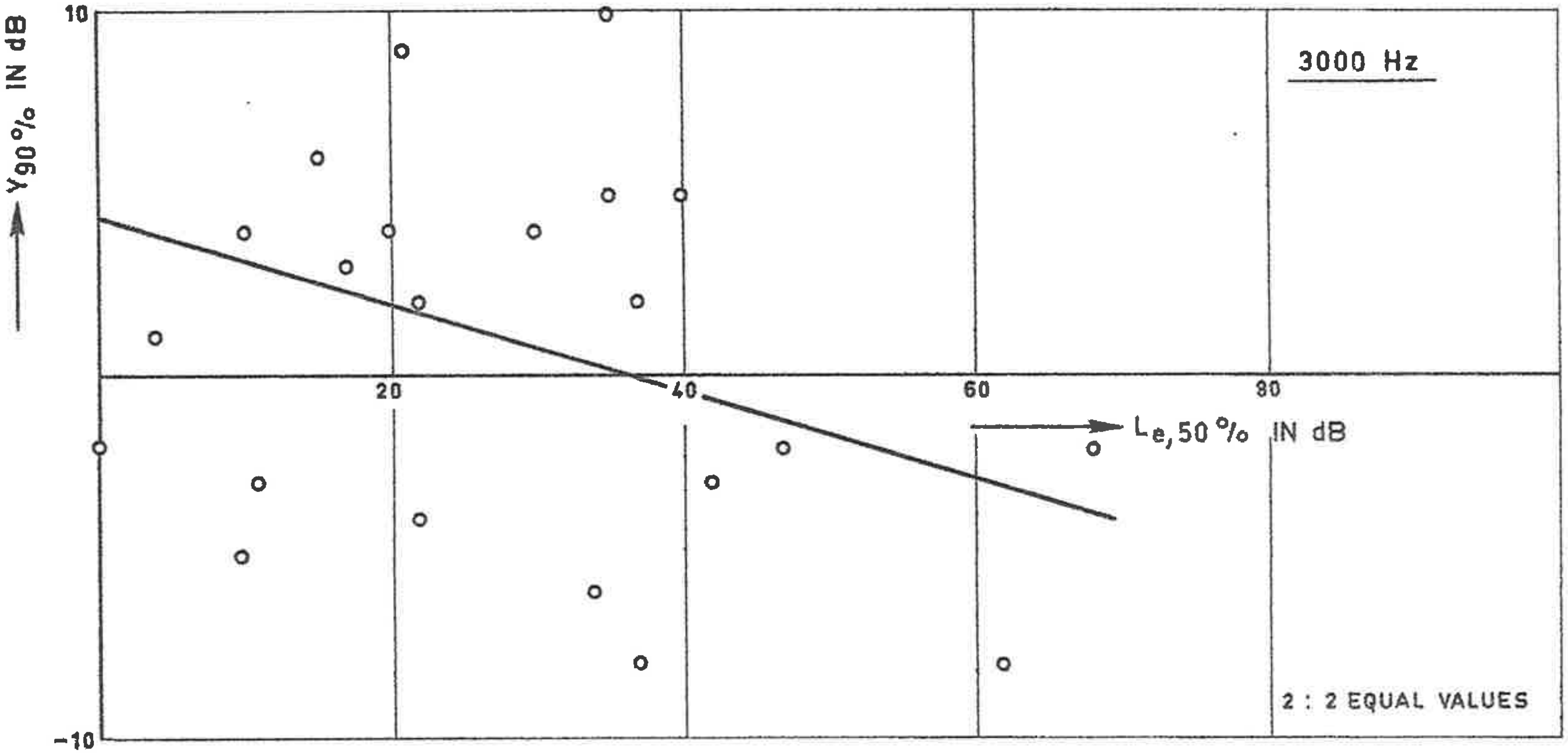

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IG-TNO AFD. GELUID EN LICHT

R35(S)-6

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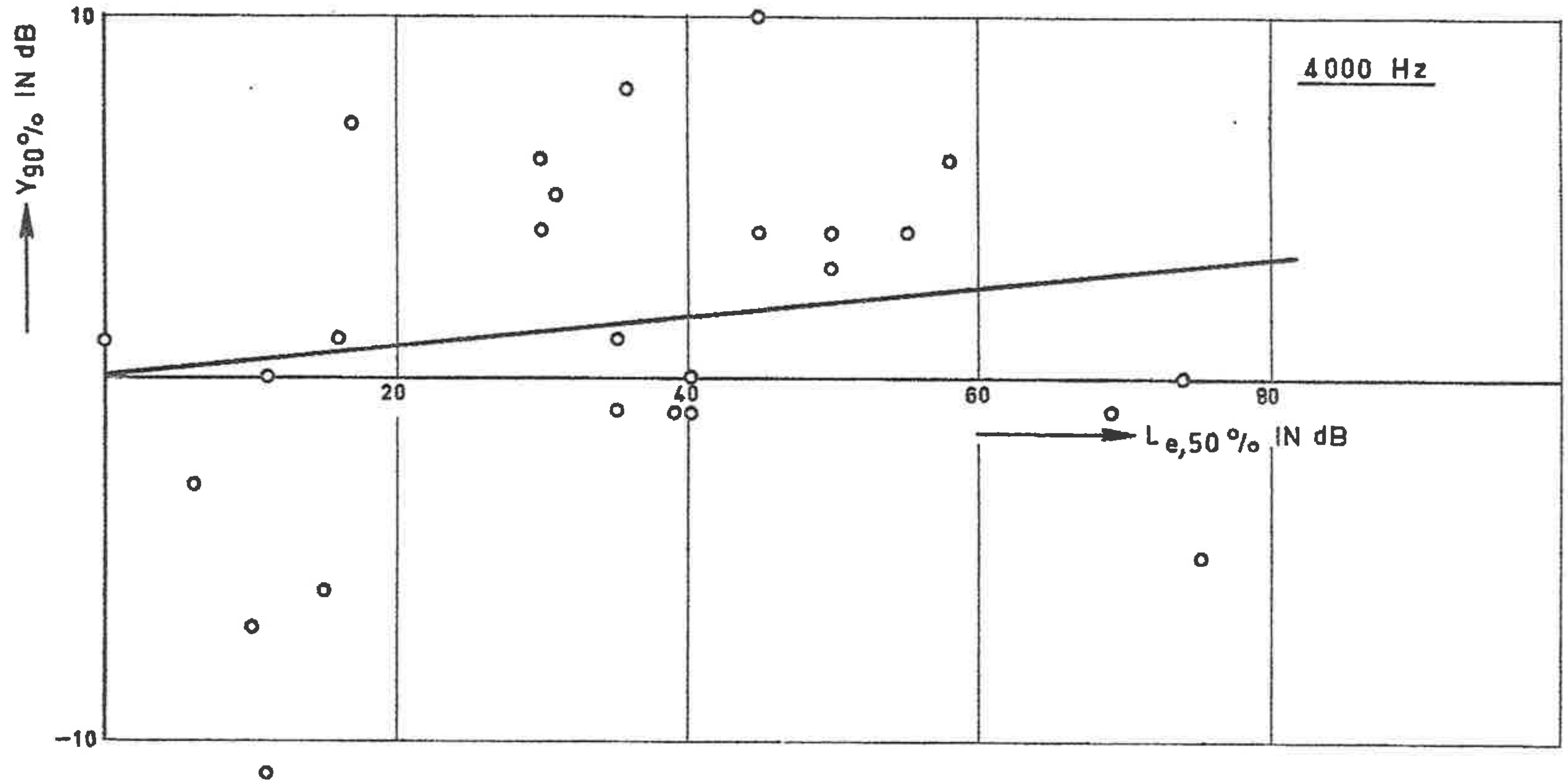
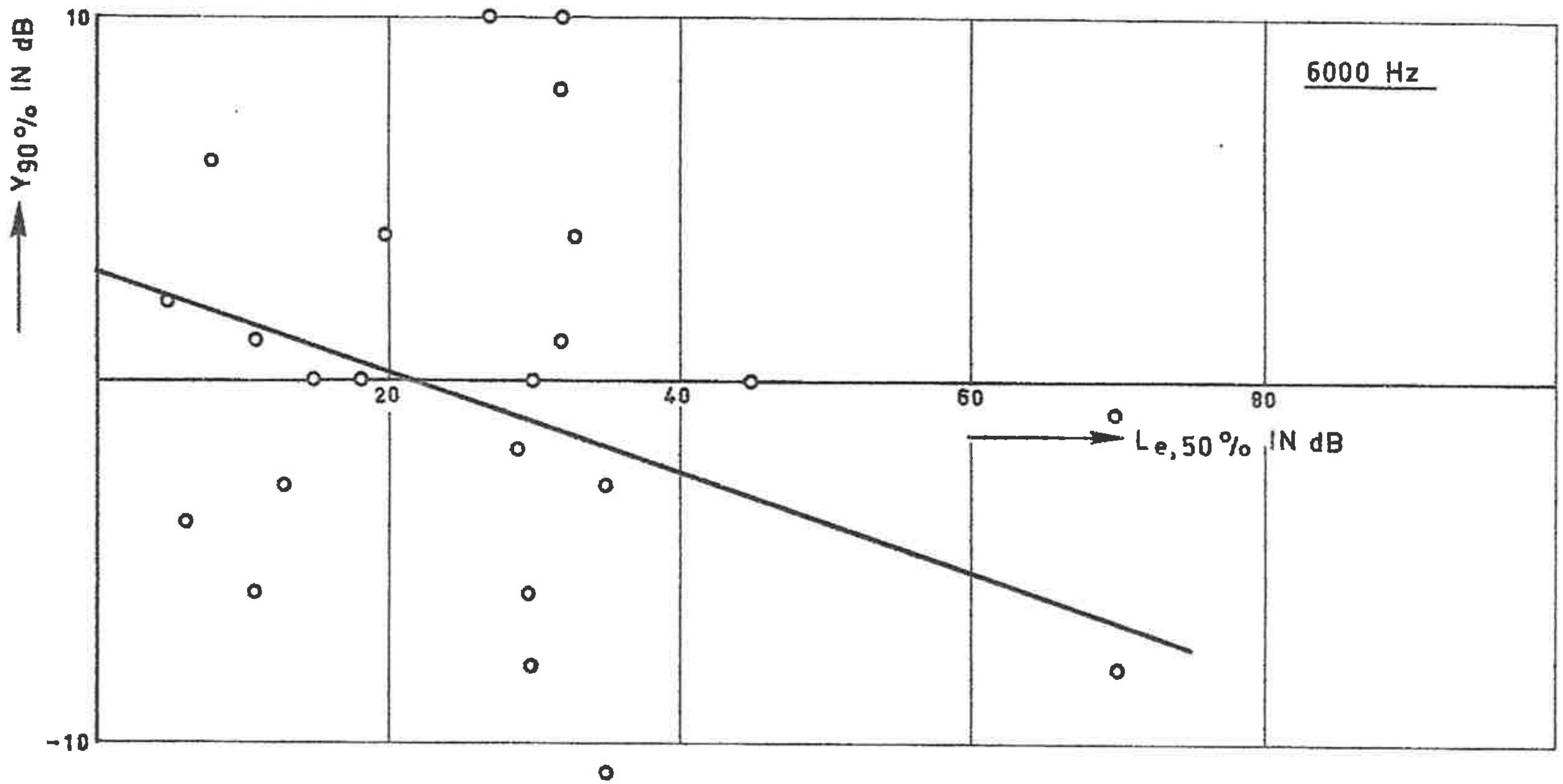
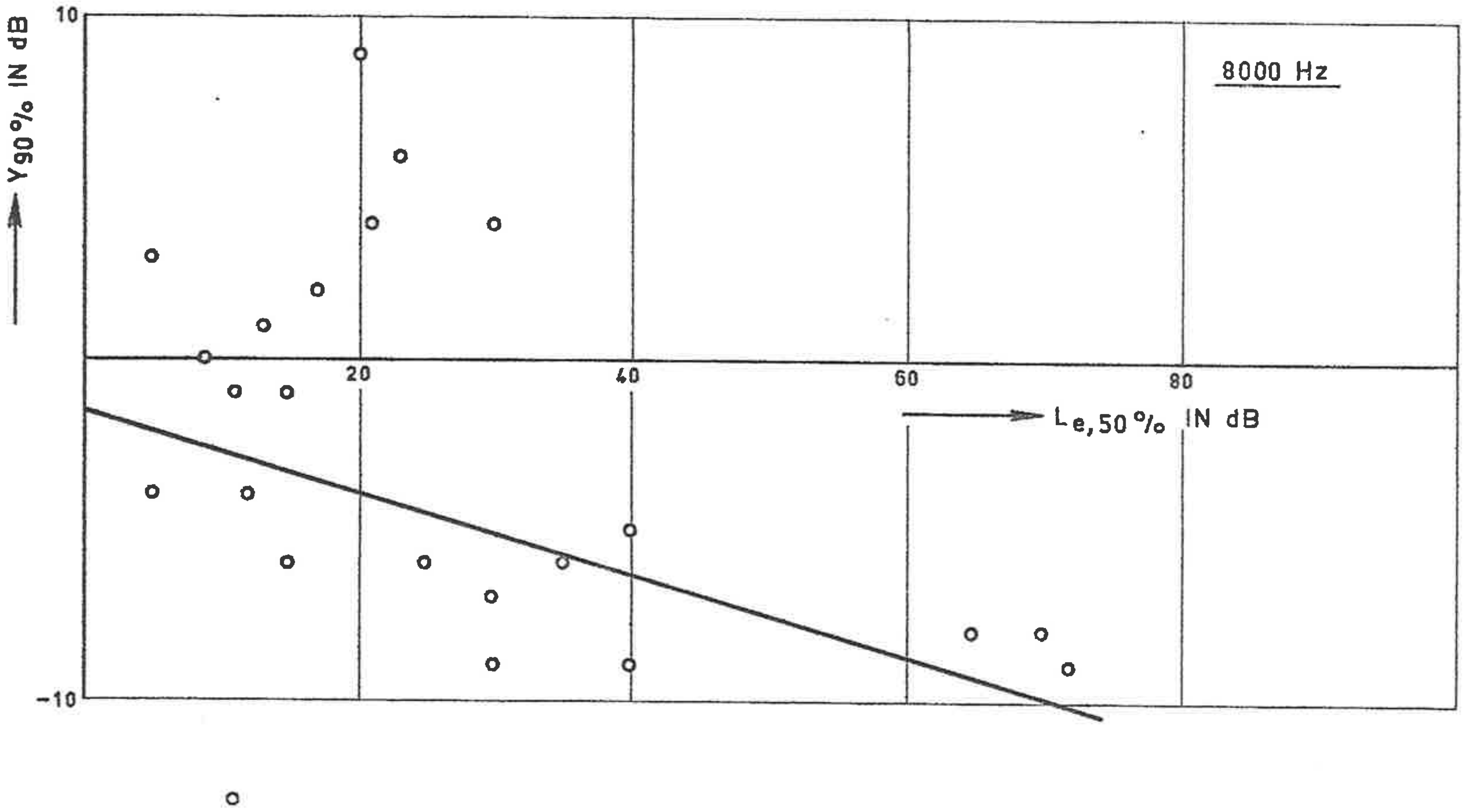


DIFFERENCE ($Y_{90\%}$) BETWEEN $L_{e,90\%}$ (ESTIMATED) AND $L_{e,90\%}$ (REAL) AS A FUNCTION OF $L_{e,50\%}$

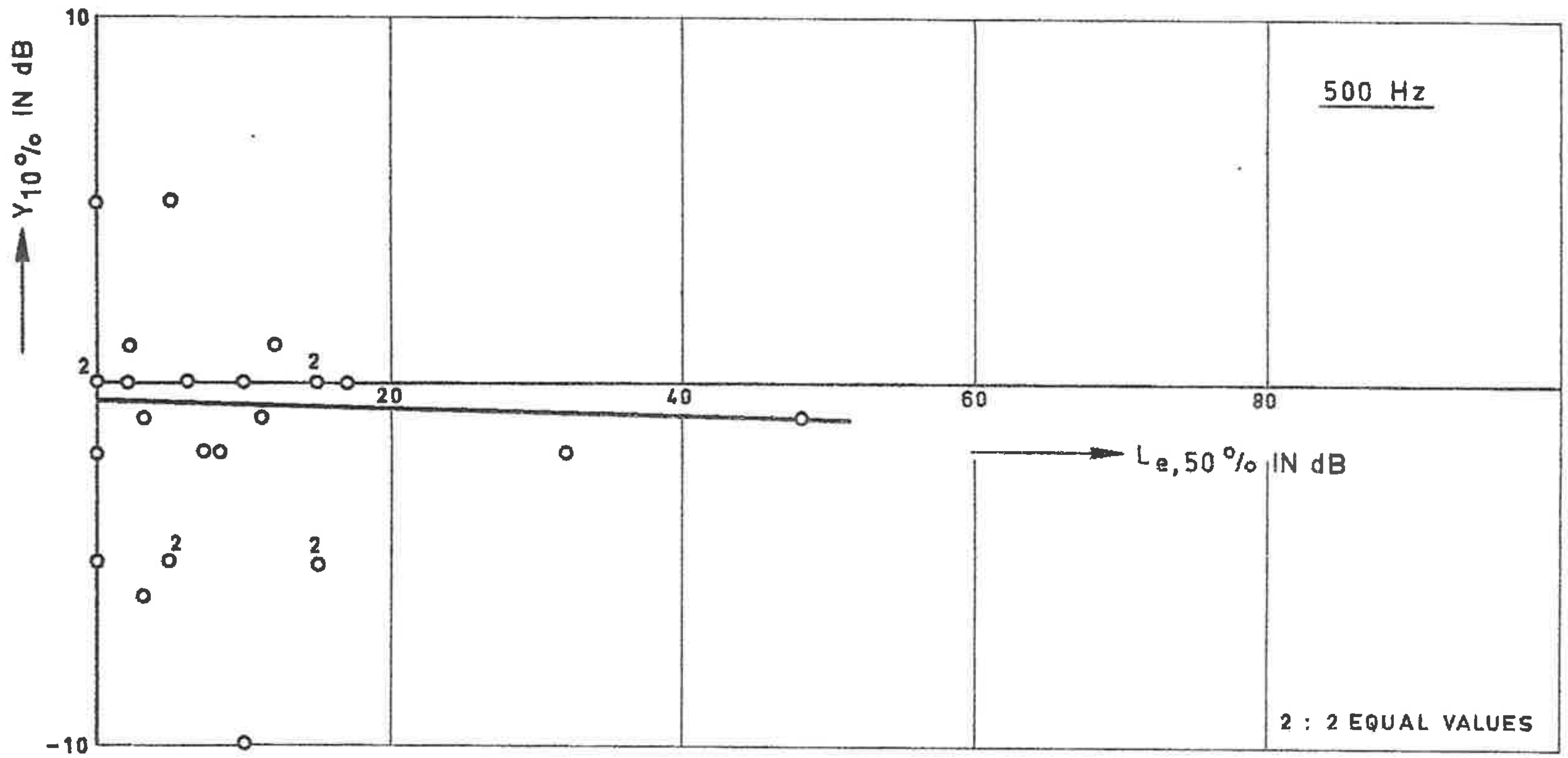


DIFFERENCE ($Y_{90\%}$) BETWEEN $L_{e,90\%}$ (ESTIMATED) AND $L_{e,90\%}$ (REAL) AS A FUNCTION OF $L_{e,50\%}$



IG-TNO AFD. GELUID EN LICHT

DIFFERENCE ($Y_{10\%}$) BETWEEN $L_{e,10\%}$ (ESTIMATED) AND $L_{e,10\%}$ (REAL) AS A FUNCTION OF $L_{e,50\%}$



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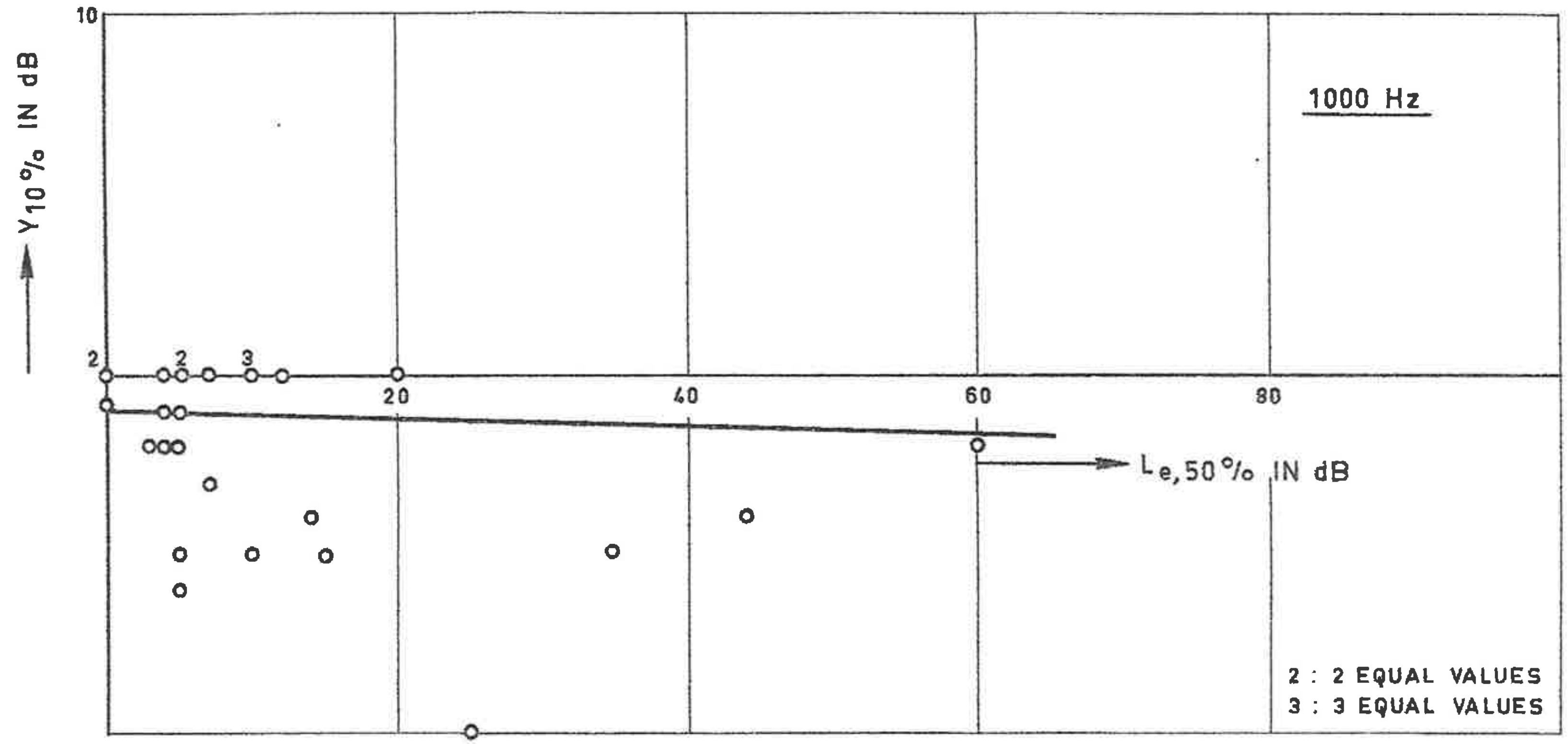
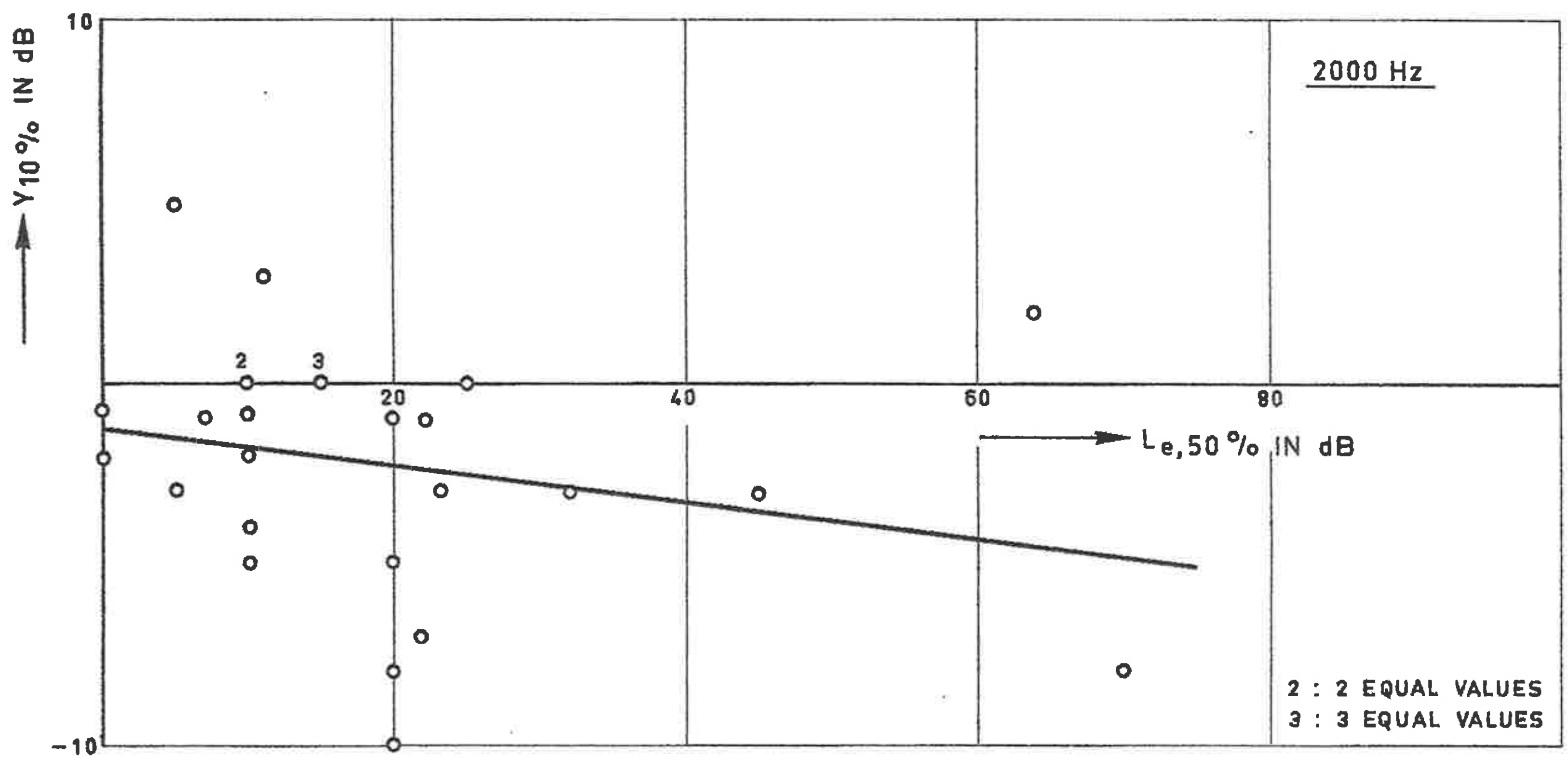
IG-TNO AFD. GELUID EN LICHT

R35 (S) - 10

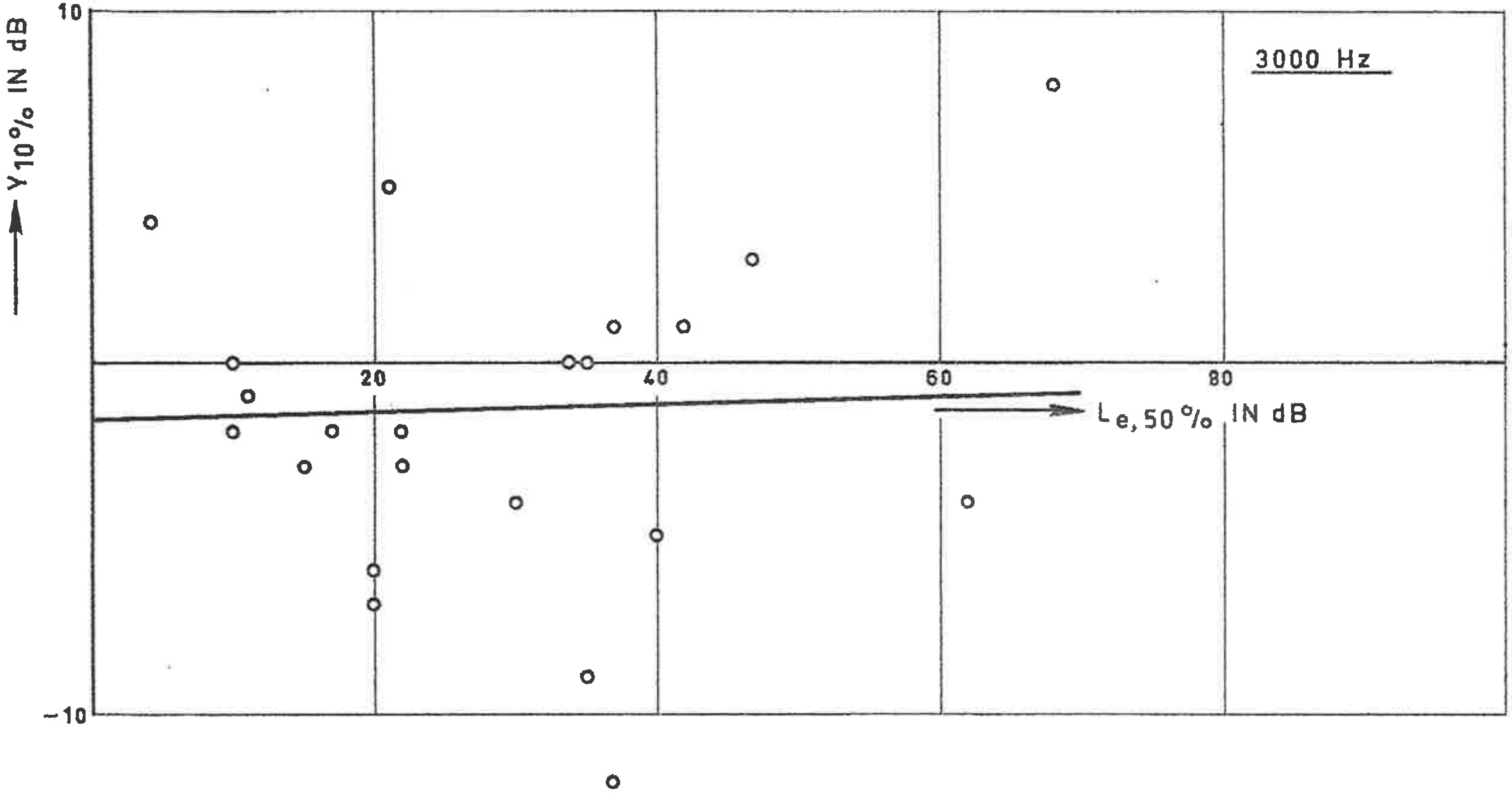
DIFFERENCE ($Y_{10\%}$) BETWEEN $L_{e,10\%}$ (ESTIMATED) AND $L_{e,10\%}$ (REAL) AS A FUNCTION OF $L_{e,50\%}$



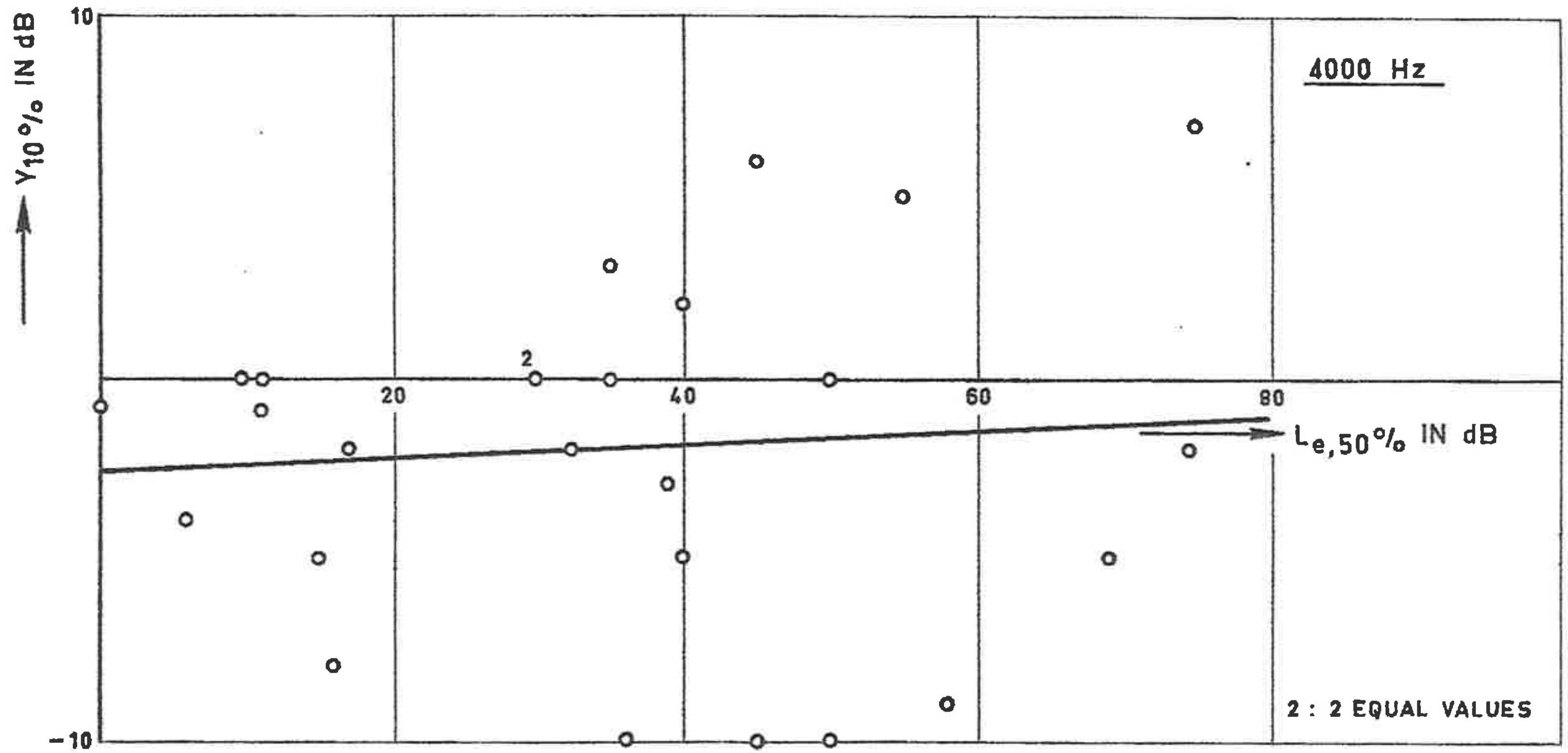
DIFFERENCE ($Y_{10\%}$) BETWEEN $L_{e,10\%}$ (ESTIMATED) AND $L_{e,10\%}$ (REAL) AS A FUNCTION OF $L_{e,50\%}$



DIFFERENCE ($Y_{10\%}$) BETWEEN $L_{e,10\%}$ (ESTIMATED) AND $L_{e,10\%}$ (REAL) AS A FUNCTION OF $L_{e,50\%}$

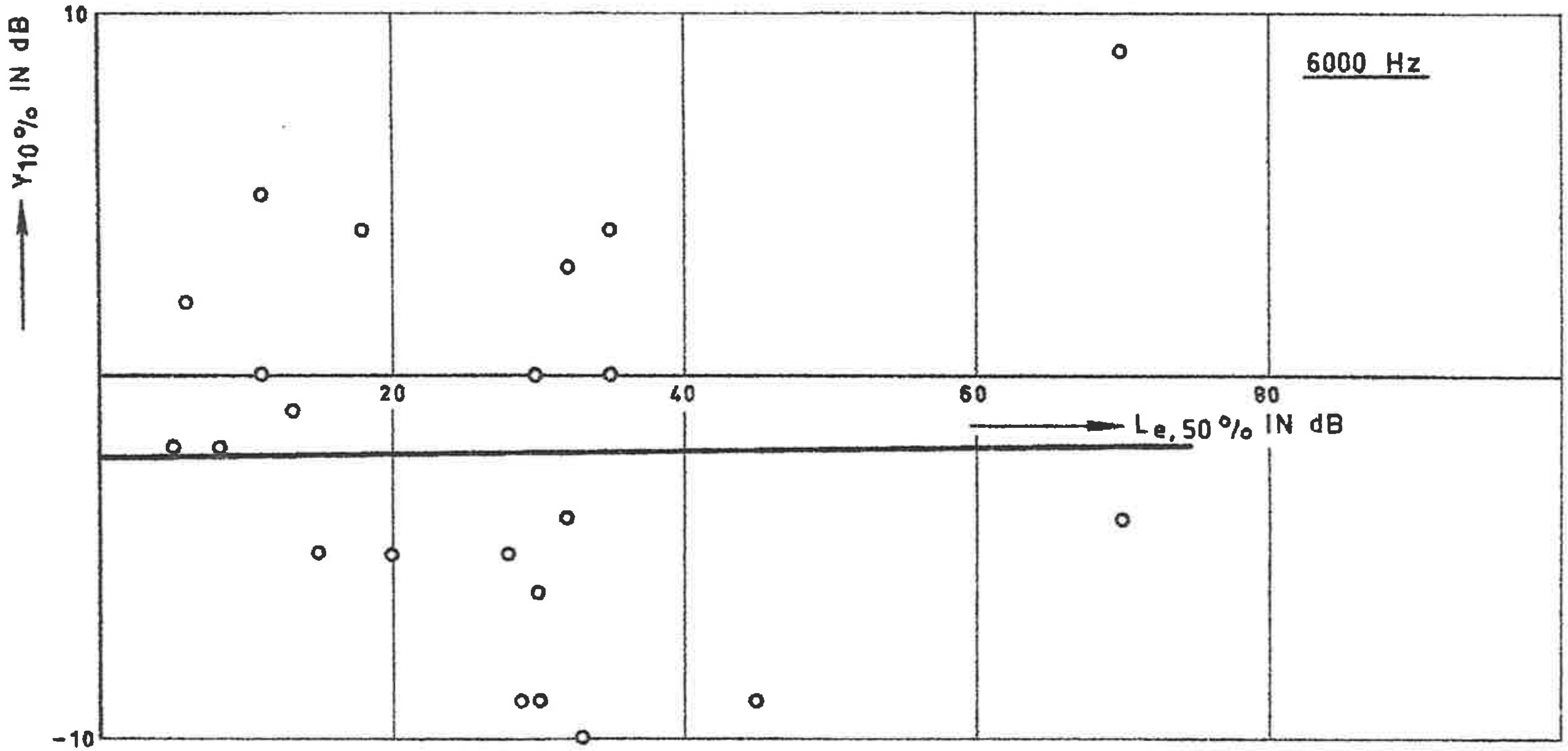


DIFFERENCE ($Y_{10\%}$) BETWEEN $L_{e,10\%}$ (ESTIMATED) AND $L_{e,10\%}$ (REAL) AS A FUNCTION OF $L_{e,50\%}$



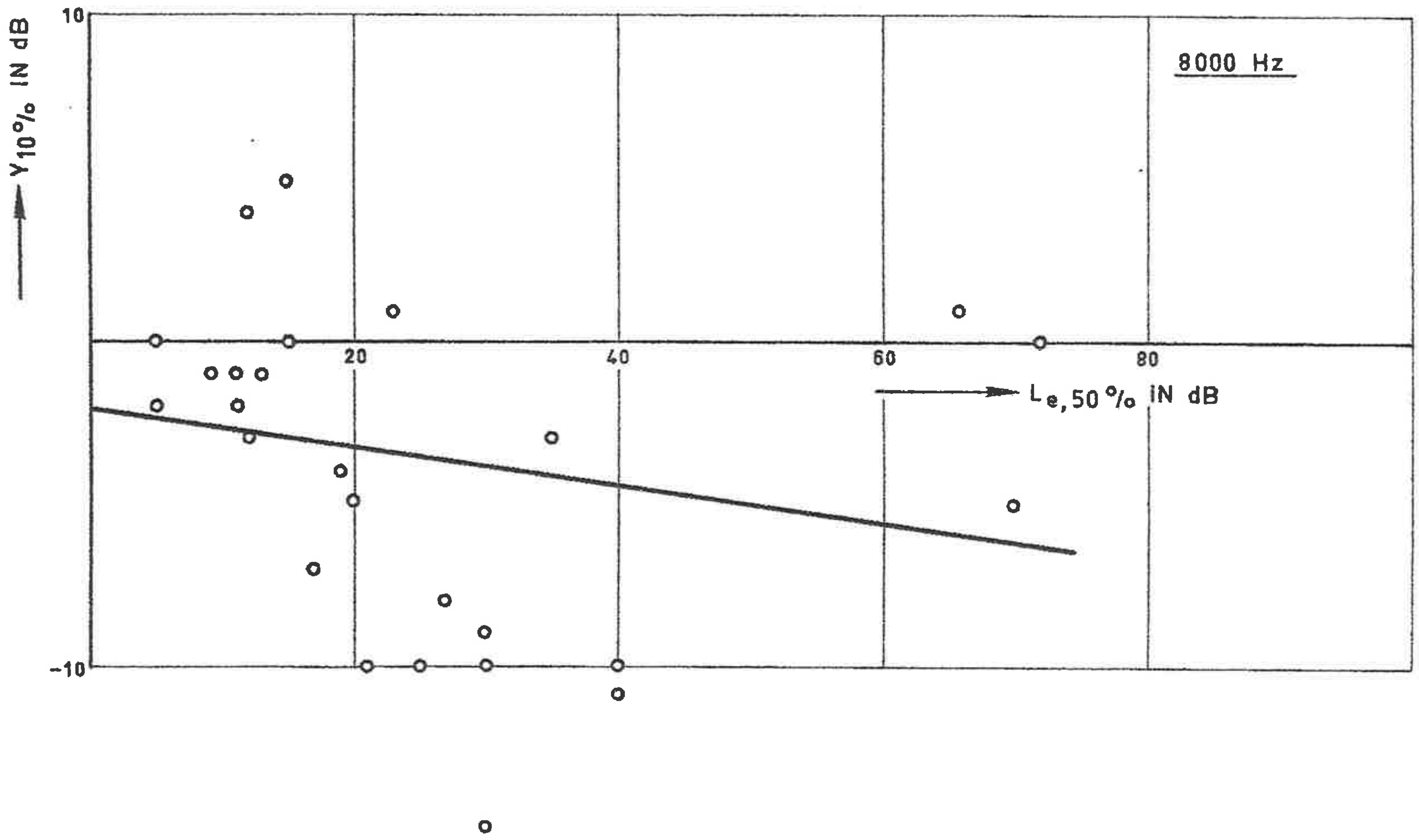
69B15
IG-TNO AFD. GELUID EN LICHT

DIFFERENCE ($Y_{10\%}$) BETWEEN $L_{e,10\%}$ (ESTIMATED) AND $L_{e,10\%}$ (REAL) AS A FUNCTION OF $L_{e,50\%}$



IG-TNO AFD. GELUID EN LICHT

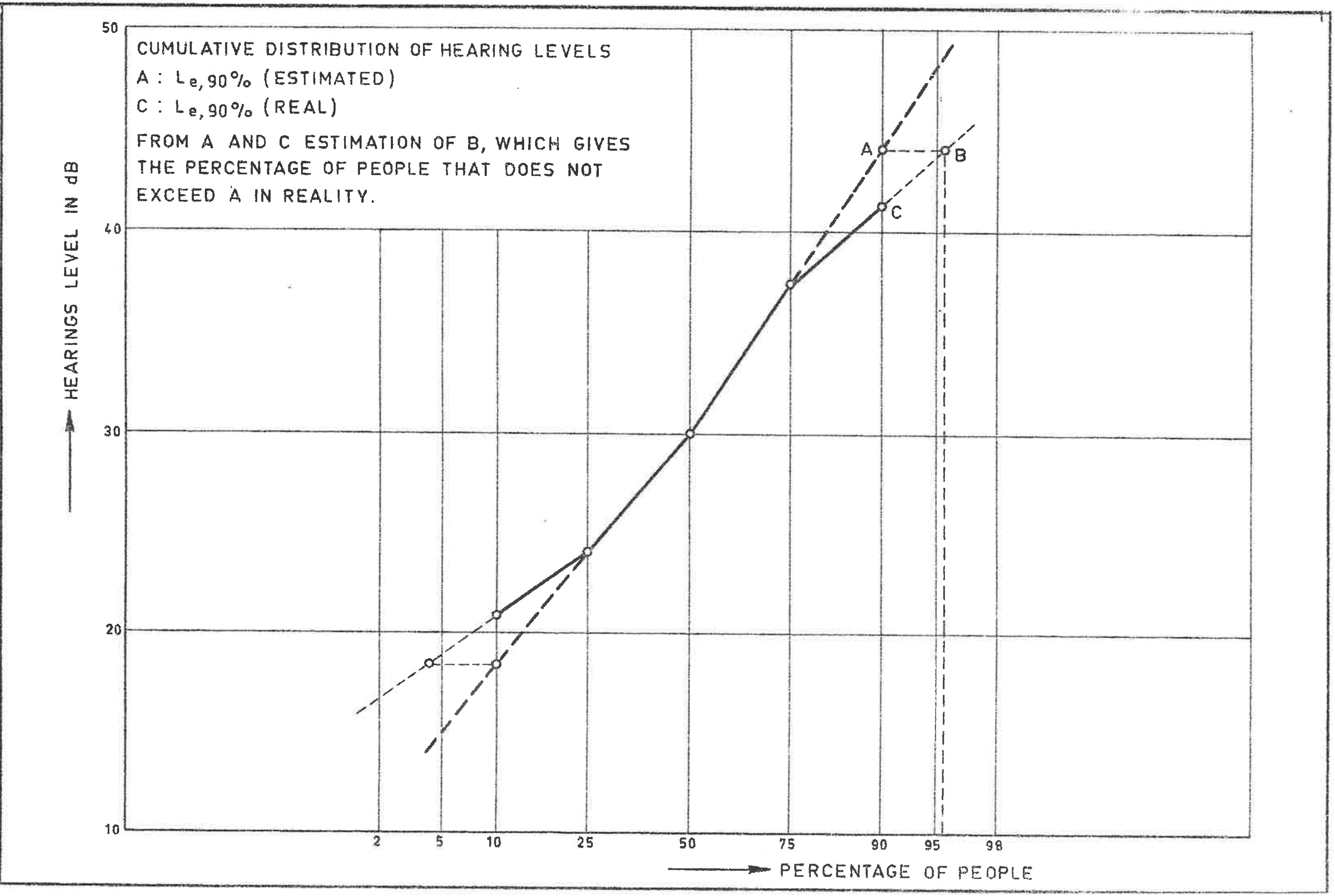
DIFFERENCE ($Y_{10\%}$) BETWEEN $L_{e,10\%}$ (ESTIMATED) AND $L_{e,10\%}$ (REAL) AS A FUNCTION OF $L_{e,50\%}$



69B18

IG-TNO AFD. GELUID EN LICHT

R35 (S) -16



$L_{e,90\%} - L_{e,50\%}$, $L_{e,75\%} - L_{e,50\%}$, $L_{e,50\%} - L_{e,25\%}$ AND $L_{e,50\%} - L_{e,10\%}$ AS A FUNCTION OF THE NOISE RATING FOR 500 TO 2000 HERTZ.