

**Typical Hearing Thresholds: a Baseline for the Assessment
of Noise-Induced Hearing Loss**

B.W. Lawton

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UNIVERSITY OF SOUTHAMPTON
INSTITUTE OF SOUND AND VIBRATION RESEARCH
HUMAN SCIENCES GROUP

**Typical Hearing Thresholds:
a Baseline for the Assessment of
Noise-Induced Hearing Loss**

by

B.W. Lawton

ISVR Technical Report No. 272

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Authorised for issue by
Professor M.J. Griffin
Group Chairman

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Summary

In claims for hearing damage due to occupational noise exposure, it is necessary to compare the measured hearing thresholds of the claimant with estimates of what his thresholds might have been, due to age alone without the noise exposure. To assess fairly the effect of the noise, a baseline is needed which gives realistic values for the natural deterioration of hearing with age.

In current practice, a claimant's hearing thresholds are judged against published hearing threshold data for "otologically normal persons" of the same age and sex. Such persons are from the population screened or selected to eliminate known hearing defects and also exposure to injurious noise. However, there is a growing realisation that such normal-for-age data are somewhat optimistic for members of the general working population. Use of the normal-for-age baseline overestimates, to some degree, the effect of the claimant's noise exposure.

Since the early 1980s, International Standards dealing with occupational hearing damage have listed baseline hearing threshold levels for two populations not exposed to significant noise: highly-screened "otologically normal persons" and also an unscreened population of what might be called "typical persons". The data listed as typical-for-age are slightly worse than those standardised as normal-for-age, to reflect the fact that most members of the general working population are not examples of otological near-perfection.

This report gives the expected range of hearing thresholds, due solely to natural ageing in a selected group of "otologically normal persons". Comparable data are also set out for the unscreened "typical persons" given in International Standards. In addition, the concept of the unselected or typical population is traced, with examples from Europe and North America.

It is suggested that, for hearing damage claims in the United Kingdom, the most appropriate baseline is the typical-for-age data found in the British National Study of Hearing. This national survey reports the observed range of hearing threshold levels, with increasing age, for British adults who have no history of noise exposure. Tables of these typical-for-age thresholds are given in this document, with advice on their interpretation.

1. Introduction

- 1.1 In compensation claims for hearing loss alleged to be due to occupational noise exposure, any medico-legal report should specify an equitable baseline against which to compare the state of the hearing of the claimant.
- 1.2 Some portion of the hearing loss of any claimant will be attributable to the natural loss of hearing sensitivity due to ageing. The remainder **might** be due to other factors such as occupational noise, socioacusis, ear disease, etc.
- 1.3 Age-related hearing loss has, for medico-legal purposes, been based upon the otologically normal population. However, such a baseline may be thought to be optimistic and unrealistic. Recent research has provided examples of hearing loss due to age in typical males and females, drawn from the general population without noise exposure but not selected for otological near-perfection.

2. Normal-for-Age Thresholds

- 2.1 The scale for Hearing Threshold Level has as its zero point the hearing thresholds of otologically normal young persons of both sexes, aged 18 to 30 years. The definition of this ‘audiometric zero’ is given in British and International standards for the calibration of audiometers; the most recent versions are found in references INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (1991) and BRITISH STANDARDS INSTITUTION (1997).
- 2.2 These Standards give a definition for an “otologically normal person”: *a person in a normal state of health, who is free from all signs and symptoms of ear disease and from obstructing wax in the ear canals, and who has no history of undue noise exposure*. This is not intended to be a medical definition: it is a scientific/technical definition for the purpose of standard-writing. However, a person who fulfils the four conditions of the definition (with the implied screening and questioning) might be considered a representative of otological near-perfection.

- 2.3 Data have been reported for the change of hearing sensitivity with age, as observed in screened samples of otologically normal persons; examples are HINCHCLIFFE (1959), CORSO (1963) and SPOOR (1967). Such survey data have been analysed by the National Physical Laboratory, in order to present overall trends. See ROBINSON and SUTTON (1978) and SHIPTON (1979).
- 2.4 On the basis of the NPL work, the growth of age-related hearing loss in otologically normal persons has been codified in ISO 7029 and BS 6951. See references INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (1984) and BRITISH STANDARDS INSTITUTION (1988) which give the shift of thresholds, relative to age 18. In order to be useful for present purposes, these age-related shifts must be adjusted slightly to give Hearing Threshold Levels in dB HL, as measured against audiometric zero: see ROBINSON (1978 and 1988a) or LAWTON (1991). Hearing Threshold Levels considered normal-for-age are given here in Table 1.
- 2.5 The normal-for-age thresholds have also been stated in Annex A to ISO 1999, which deals in part with the estimation of noise-induced hearing loss. See INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (1982, 1985, 1990). These normal-for-age values are sometimes referred to as database A of ISO 1999, and are referenced back to ISO 7029 which itself is based solely upon the NPL work.

3. Typical-for-Age Thresholds

- 3.1 The Draft International Standard ISO 1999 of 1982 was widely circulated for public comment, as a sort of 'notice of proposed rule-making'. It contained a procedure for combining age-associated hearing loss and noise-induced hearing damage to give the total Hearing Threshold Level expected at each audiometric frequency. In addition to the normal-for-age thresholds of Annex A (for screened, otologically normal persons), values were also given in Annex B for one example of a typical unscreened/unselected population of males and females in an industrialized society. The particular example of Annex B was derived by JOHNSON (1978) working on US data reported by

GLORIG and ROBERTS (1965). Annex B was later reproduced in the revised Draft International Standard ISO 1999 of 1985 and also the final version of 1990.

- 3.2 The US typical-for-age hearing threshold values of ISO 1999 Annex B are given here in Table 2, with corrections by CLARK and BOHL (1992).
- 3.3 The hearing threshold data of Annex B were recognised as not necessarily appropriate world-wide. Differences were expected between nations, in respect of life-style, social/recreational noise exposure, incidence of disease, and the use of potentially ototoxic drugs. In recognition of such national differences, ISO 1999 recommended the use of a database B of typical hearing for the “country under consideration”. Such data for the typical population, not occupationally exposed to noise, would provide an appropriate national baseline against which to compare the hearing of noise-exposed groups within the population. Such typical data are available for the United Kingdom (see 4.2).

4. Examples of Typical-for-Age Thresholds

- 4.1 A number of datasets have been reported, giving the effect of age upon hearing thresholds for typical persons, not selected for otological normality. See for example: NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH (1972), THIÉRY et al (1979), ROYSTER and THOMAS (1979), MOLVÆR et al (1983), ROBINSON (1988 a,b 1991), PASSCHIER-VERMEER (1988, 1990, 1991), LUTMAN et al (1991, 1993, 1994, 1996), CLARK and BOHL (1993, 1996), DAVIS (1995), and HEALTH and SAFETY EXECUTIVE (1995).
- 4.2 The results of the UK National Study of Hearing are reported by DAVIS (1995). This Study was performed by the Institute of Hearing Research of the Medical Research Council, to describe the state of hearing of the British population within various age bands. Included are the ranges of thresholds for males and females, not exposed to significant occupational noise, and without conductive hearing loss. These typical-for-age thresholds might be considered an appropriate national database B, not

screened for otological normality. Some of the survey results are given here in Table 3.

5. General Points on the Use of any Dataset

- 5.1 A claimant might be compared with the median (50%) threshold expected for hearing loss due to ageing. Such an approach could be misleading as no indication of expected variation is given: small deviations from the median-for-age thresholds might be thought significant. Theoretically, no person is at the median: half of the population has worse thresholds than the median value, with the other half having better hearing. In addition, it is unlikely that any person's thresholds would follow the median across the range of audiometric frequencies.
- 5.2 A different and perhaps more helpful practice would be to give a range of thresholds considered representative of undamaged hearing. Do the claimant's hearing threshold levels fall inside or outside of the range 25% to 75% for the distribution of age-associated hearing loss? In other words, how does the claimant compare with the middle HALF of the undamaged (non-noise-exposed) population?

6. Which? Normal or Typical?

- 6.1 It must be kept in mind that otological normality (as defined in the Standards cited above) must be demonstrated or proved, not accepted by default. Judgement by a medical examiner that a hearing loss claimant is 'clinically normal' (not ill) is not the same as classification of that claimant as 'otologically normal' (near perfect).
- 6.2 Any hearing damage claimant will have a history of some degree of occupational noise exposure. The question to answer is: Would the claimant be 'otologically normal' in all respects except for the reported noise exposure?
- 6.3 The medical examiner can verify the claimant to be *free from obstructing wax in the ear canals*.

- 6.4 Now, the decision process reaches an important branch point. Any claimant judged ‘clinically normal’ is certainly a member of the typical population, but only a fraction of typical persons will be ‘otologically normal’. Should the claimant under examination be rigorously screened for otological normality, or simply accepted as typical without screening?
- 6.5 The medical examiner can perform a coarse screen, seeking reasons for **rejection** from the normal class. The ears may be inspected for *all signs of ear disease*. A judgement of ‘clinically normal’ means not diseased, disordered or deformed. This is not the judgement required. Any visible sign of ear disease or surgery, past or present, should be reported, with the result that the claimant is specifically excluded from the otologically normal population. Any report by the claimant of ear disease *symptoms* would also result in exclusion from the normal population.
- 6.6 If the medical examiner does observe *signs of ear disease* past or present, is the pathology of such a degree as to classify the ear(s) as ‘abnormal’? If so, it might be argued that the claimant should be excluded from the typical population, as well as the otologically normal.
- 6.7 Is the claimant in a *normal state of health*? As a class, older persons are subject to some degree of ill health with associated hearing risk. Some not uncommon diseases of middle and later age are thought to have some adverse effect upon the hearing, e.g. diabetes and cardiovascular problems. An ENT specialist may ask about general health, but is unlikely to verify the absence of diseases or conditions carrying hearing risk.

7. **Conclusions**

- 7.1 It is doubtful whether any older hearing loss claimant would be considered otologically normal, even without his occupational noise exposure. Most people accumulate hearing risk factors with increasing age.

- 7.2 It is unlikely that any hearing loss claimant has been verified as a member of the otologically normal population.
- 7.3 It is more likely than not that any hearing damage claimant is a member of the typical population.
- 7.4 The degree of any 'excess' hearing loss, due possibly to injurious noise exposure, may be judged by comparison with hearing thresholds considered typical-for-age for the non-exposed population. This concept has been recognized world-wide since 1982, when it was written into a Draft International Standard.
- 7.5 The UK National Study of Hearing by the IHR/MRC determined Hearing Threshold Levels for British persons **not** exposed to significant occupational noise (Table 3). The results were reported for males and females in certain age bands. These typical-for-age thresholds should be adopted as the national database against which to compare hearing thresholds of workers claiming noise-induced hearing loss.

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soumise à des bruits d'origine professionnelle [Study of hearing of an urban
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Table 1

Hearing Threshold Levels expected for various fractions of otologically normal males and females, at stated ages. The values are based upon the threshold shifts (relative to age 18) given in the NPL tables of SHIPTON (1979), later standardized in ISO 7029. On the audiograms below, the irregular shaded area represents the threshold range between the better-hearing 25% and the worse-hearing 75% of the population. Half of non-noise-exposed otologically normal males or females would fall within the range given.

Part A. Age 20

freq., kHz	0.25	0.5	1	2	3	4	6	8
males								
10%	-4	-5	-7	-8	-9	-9	-5	-8
25%	-1	-2	-4	-5	-5	-5	0	-3
50%	3	1	-1	-1	-1	0	5	4
75%	8	5	4	4	4	6	12	10
90%	12	9	7	8	9	11	17	17
females								
10%	-3	-5	-7	-8	-8	-8	-4	-8
25%	0	-2	-4	-5	-5	-4	0	-3
50%	3	1	-1	-1	-1	0	5	3
75%	7	5	4	4	4	5	11	10
90%	11	9	7	8	8	10	16	17

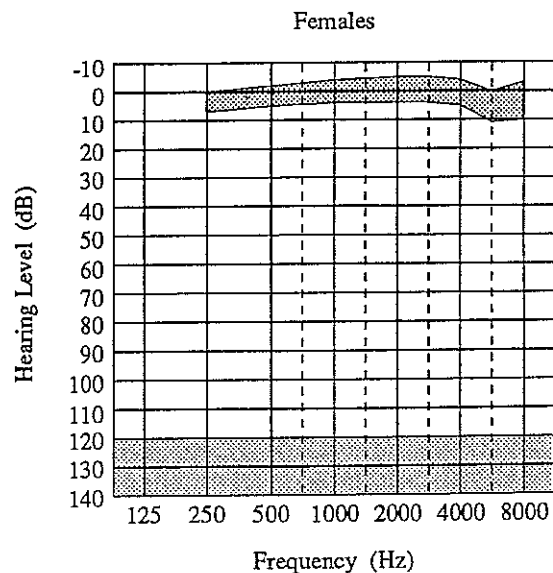
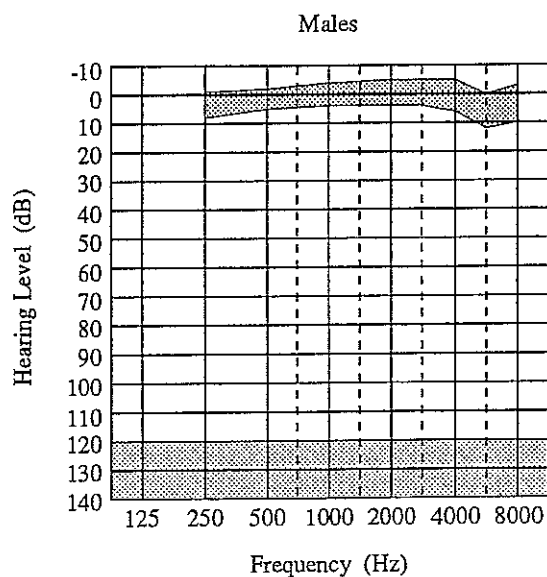


Table 1 continued

Hearing Threshold Levels for various fractions of otologically normal males and females.

Part B. Age 30

freq., kHz	0.25	0.5	1	2	3	4	6	8
males								
10%	-4	-5	-7	-8	-8	-7	-3	-6
25%	0	-2	-3	-4	-4	-3	2	0
50%	3	2	0	0	1	2	8	6
75%	8	6	4	5	6	9	15	14
90%	12	10	8	10	12	14	21	22
females								
10%	-3	-5	-7	-7	-8	-7	-3	-7
25%	0	-2	-3	-4	-4	-3	2	-1
50%	3	2	0	0	0	1	7	5
75%	8	6	4	5	5	7	13	13
90%	12	10	8	9	10	12	19	20

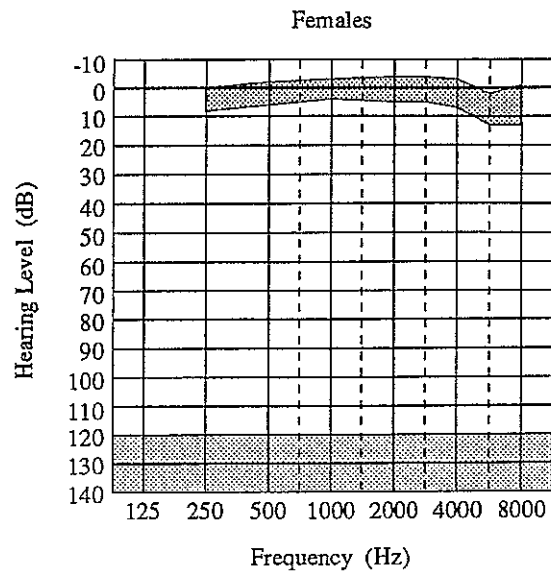
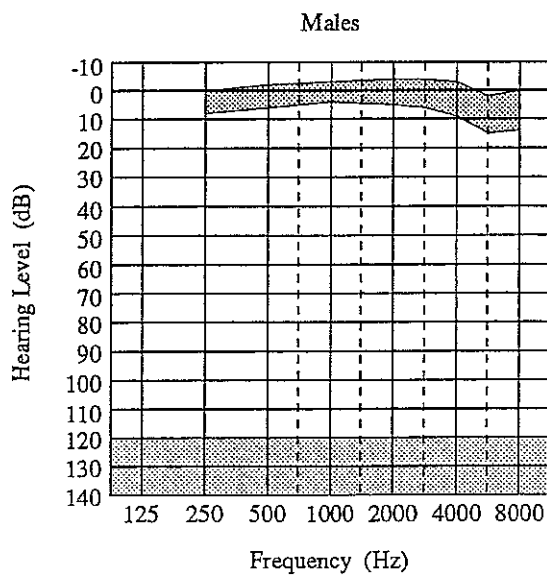


Table 1 continued

Hearing Threshold Levels for various fractions of otologically normal males and females.

Part C. Age 40

freq., kHz	0.25	0.5	1	2	3	4	6	8
males								
10%	-3	-4	-6	-7	-6	-4	0	-2
25%	1	-1	-2	-2	-1	1	7	5
50%	5	3	1	2	5	8	14	14
75%	9	7	6	8	12	16	24	24
90%	14	12	10	14	18	23	31	33
females								
10%	-3	-4	-6	-6	-6	-6	-1	-4
25%	1	-1	-2	-2	-2	-1	5	3
50%	5	3	1	2	3	4	11	10
75%	9	7	6	7	9	11	19	20
90%	13	12	10	12	14	17	26	28

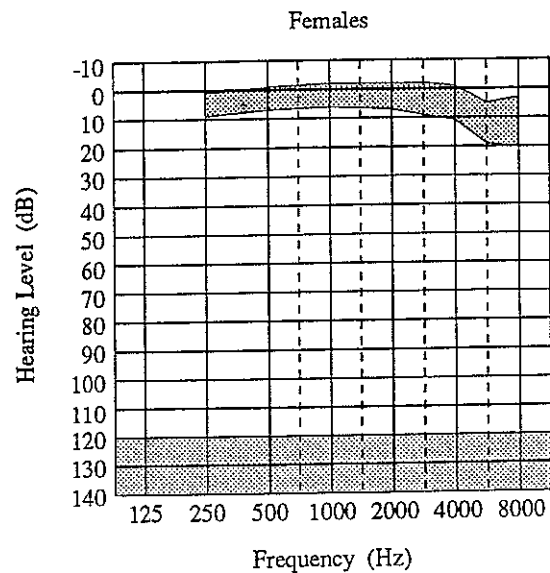
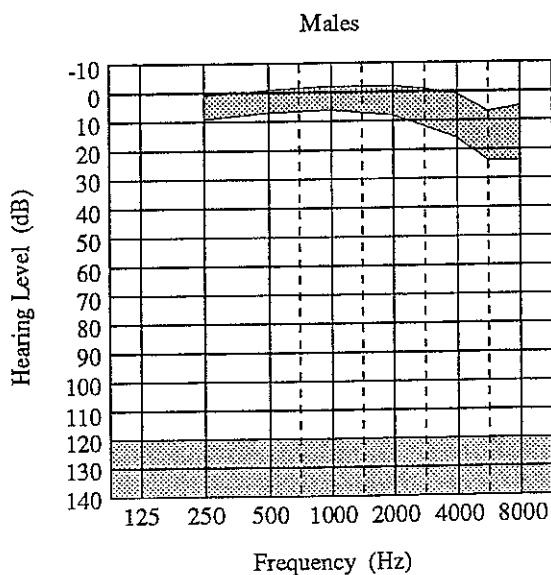


Table 1 continued

Hearing Threshold Levels for various fractions of otologically normal males and females.

Part D. Age 50

freq., kHz	0.25	0.5	1	2	3	4	6	8
males								
10%	-2	-3	-5	-5	-3	0	5	4
25%	2	0	-1	1	4	8	14	14
50%	6	4	4	6	10	16	23	26
75%	12	10	9	13	20	27	35	39
90%	16	15	14	20	28	36	46	52
females								
10%	-2	-3	-5	-5	-4	-3	3	1
25%	2	0	-1	0	1	3	10	9
50%	6	5	4	5	7	9	17	18
75%	11	10	9	12	14	17	27	30
90%	16	15	14	17	20	24	36	71

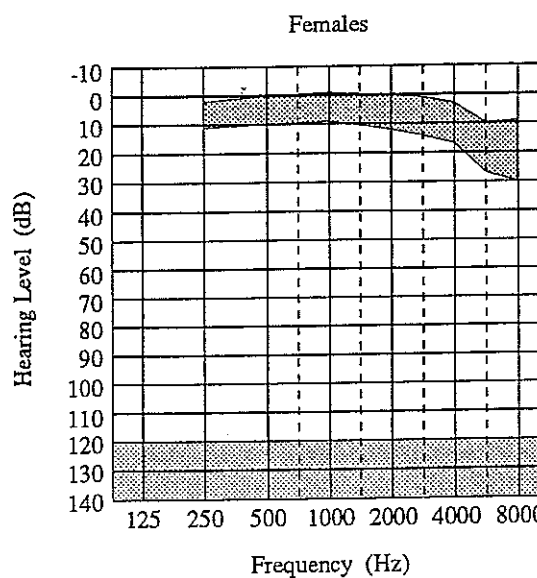
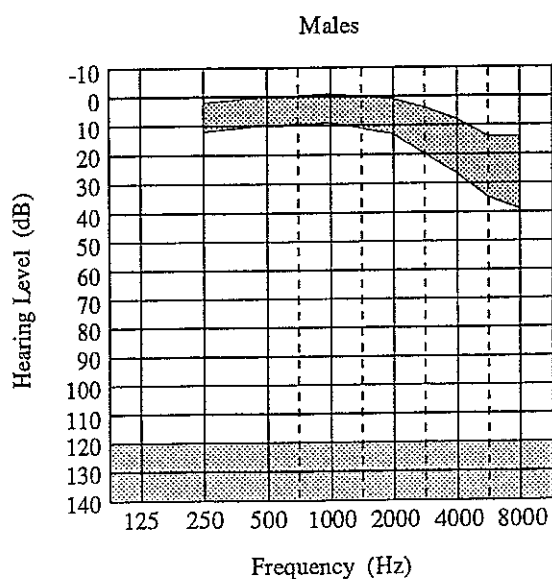


Table 1 continued

Hearing Threshold Levels for various fractions of otologically normal males and females.

Part E. Age 60

freq., kHz	0.25	0.5	1	2	3	4	6	8
males								
10%	-1	-2	-3	-2	2	7	13	13
25%	3	2	2	5	10	17	24	27
50%	8	7	7	11	19	28	37	42
75%	14	13	13	20	31	42	53	61
90%	20	18	18	28	43	55	67	78
females								
10%	0	-2	-3	-2	-1	1	7	7
25%	4	2	2	3	5	8	16	17
50%	8	7	7	10	12	16	26	30
75%	14	13	13	17	21	26	39	45
90%	19	19	18	24	29	35	50	58

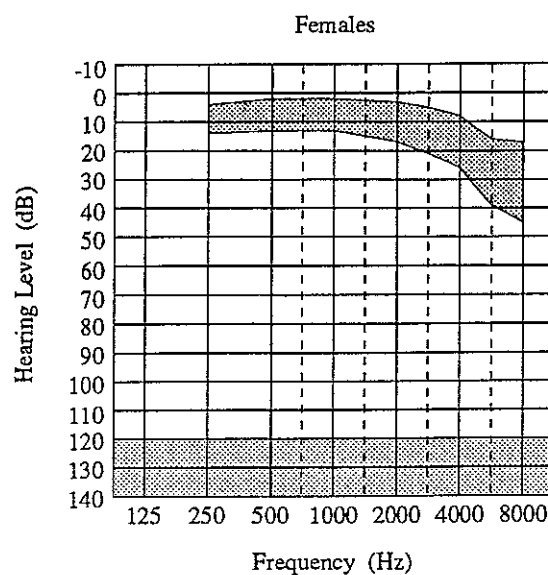
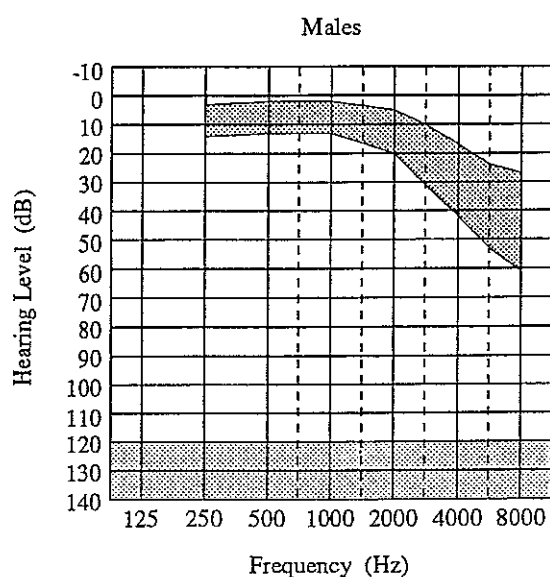


Table 1 concluded

Hearing Threshold Levels for various fractions of otologically normal males and females.

Part F. Age 70

freq., kHz	0.25	0.5	1	2	3	4	6	8
males								
10%	1	0	-1	2	8	15	23	25
25%	6	5	4	10	18	28	37	43
50%	11	11	10	18	30	43	54	63
75%	18	17	18	29	45	62	75	80+
90%	24	24	24	38	58	79	80+	80+
females								
10%	1	0	-1	1	3	5	14	14
25%	6	5	4	8	11	14	25	28
50%	11	11	10	15	19	24	37	43
75%	18	17	18	25	30	37	53	63
90%	24	24	24	33	40	48	67	80

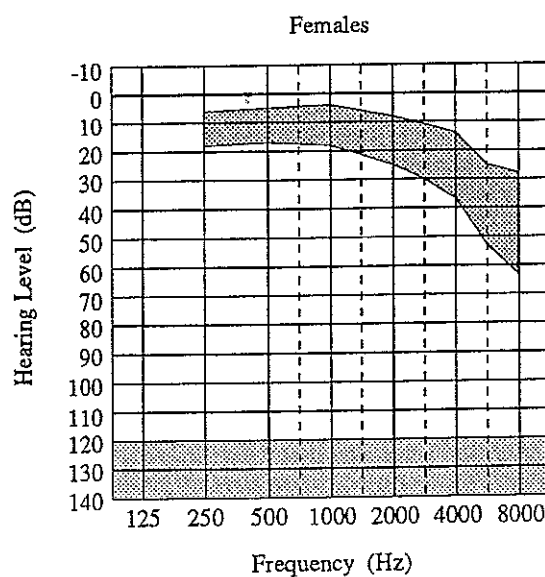
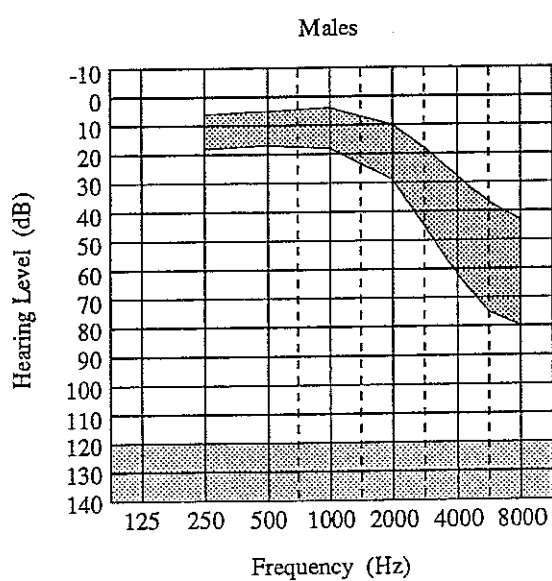


Table 2

Hearing Threshold Levels expected for various fractions of typical unscreened males and females, at stated ages. The values, for the better ear, are derived from Annex B of ISO 1999. On the audiograms below, the irregular shaded area represents the threshold range between the better-hearing 25% and the worse-hearing 75% of the population. Half of non-noise-exposed typical unscreened males or females would fall within the range given.

Part A. Age 30

freq., kHz	0.5	1	2	3	4	6
males						
10%	-1	-5	-4	-1	-1	8
25%	3	-3	-2	3	3	12
50%	7	0	2	9	10	18
75%	11	4	7	17	20	27
90%	15	10	13	30	38	48
females						
10%	-1	-6	-6	-4	-5	3
25%	2	-3	-4	0	-1	7
50%	6	1	0	4	4	12
75%	10	5	5	9	9	18
90%	15	9	10	13	16	25

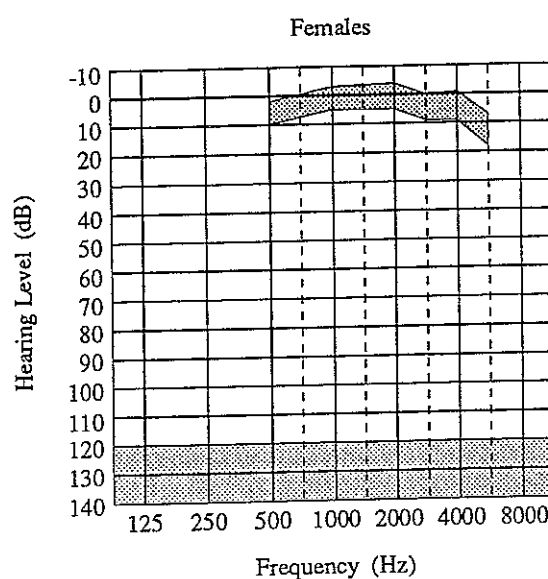
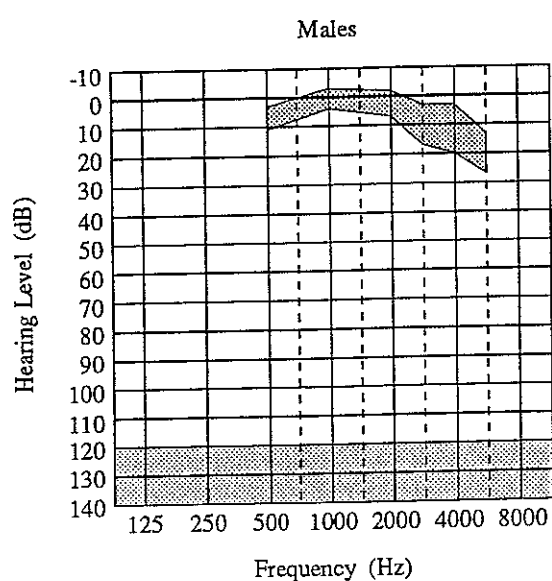


Table 2 continued

Hearing Threshold Levels for various fractions of typical unscreened males and females.

Part B. Age 40

freq., kHz	0.5	1	2	3	4	6
males						
10%	0	-4	-3	2	4	11
25%	4	-1	0	6	9	16
50%	8	3	4	13	17	24
75%	13	7	10	23	28	35
90%	19	15	19	41	50	62
females						
10%	0	-5	-4	-2	-4	5
25%	3	-2	-2	2	1	9
50%	7	2	2	6	6	15
75%	12	7	7	11	12	22
90%	19	13	13	18	18	31

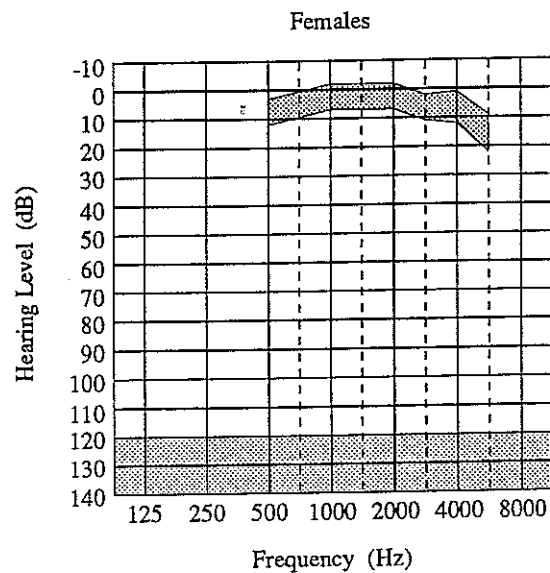
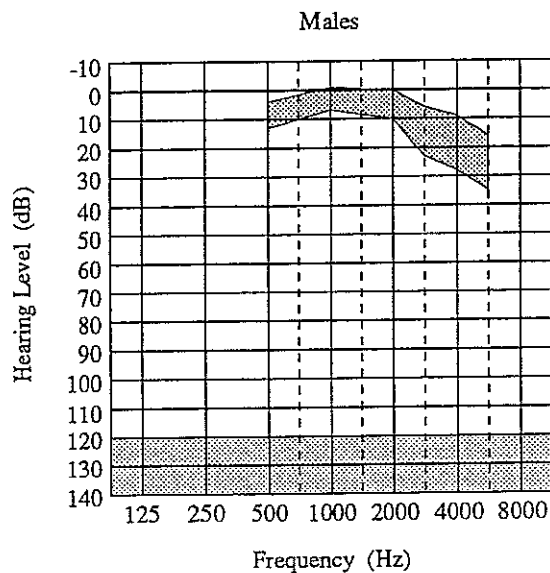


Table 2 continued

Hearing Threshold Levels for various fractions of typical unscreened males and females.

Part C. Age 50

freq., kHz	0.5	1	2	3	4	6
males						
10%	1	-3	-2	5	8	17
25%	5	1	2	11	16	23
50%	10	5	8	19	26	31
75%	15	10	16	30	38	43
90%	21	16	28	51	54	64
females						
10%	1	-4	-2	0	-1	8
25%	5	-1	1	4	3	13
50%	10	4	6	9	9	20
75%	16	10	12	15	17	30
90%	23	16	23	26	26	45

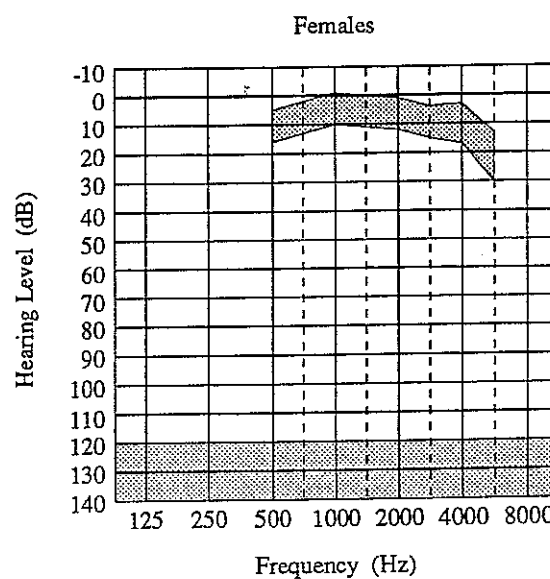
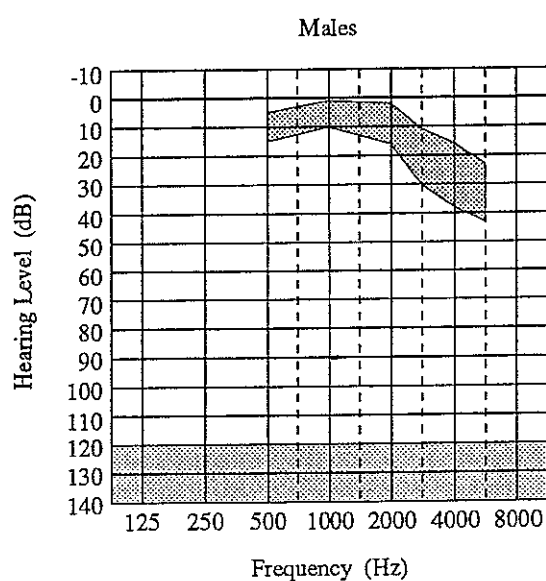


Table 2 concluded

Hearing Threshold Levels for various fractions of typical unscreened males and females.

Part D. Age 60

freq., kHz	0.5	1	2	3	4	6
males						
10%	2	-2	0	9	12	22
25%	7	2	4	18	23	32
50%	12	6	10	30	36	46
75%	18	12	22	44	52	61
90%	26	21	43	62	68	80
females						
10%	4	-2	0	3	4	15
25%	9	2	3	9	9	21
50%	14	7	8	16	17	29
75%	22	13	16	25	27	42
90%	29	21	29	37	43	57

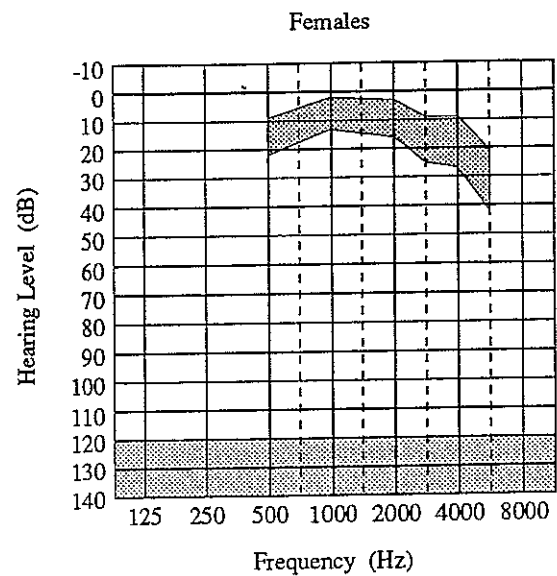
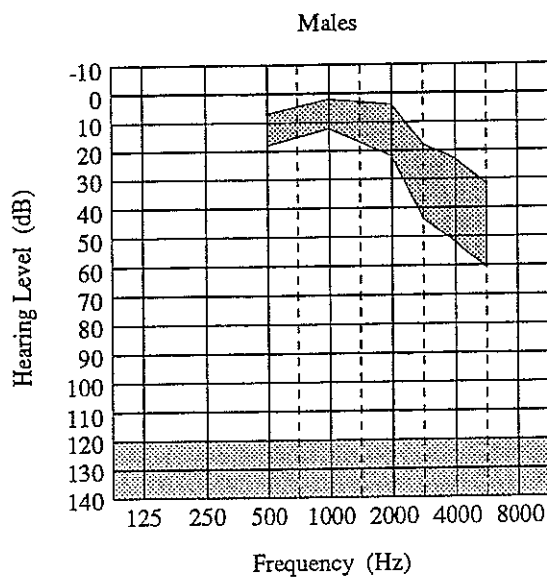


Table 3

Hearing Threshold Levels expected for various fractions of typical British males and females, at stated ages. The values, indicating the average of both ears, are derived from the National Study of Hearing reported by DAVIS (1995). On the audiograms below, the irregular shaded area represents the threshold range between the better-hearing 25% and the worse-hearing 75% of the population. Half of non-noise-exposed typical British males or females, without conductive hearing loss, would fall within the range given.

Part A. Age 18-30

freq., kHz	0.25	0.5	1	2	3	4	6	8
males								
10%	2	-4	-4	-4	-7	-3	1	-3
25%	4	1	1	-1	-3	1	7	1
50%	9	6	2	4	3	7	13	6
75%	12	10	8	7	10	12	19	14
90%	18	13	11	13	21	21	29	24
females								
10%	1	-1	-2	-2	-3	-2	3	-3
25%	5	2	1	2	2	3	9	4
50%	8	5	4	5	6	7	15	9
75%	11	8	8	9	10	12	20	13
90%	15	13	12	15	15	16	27	21

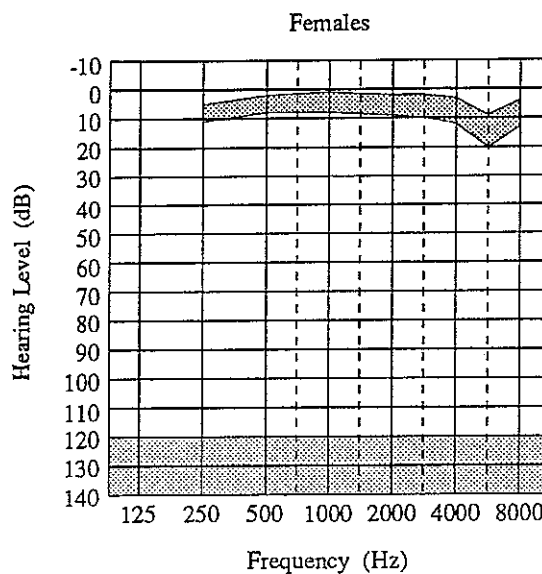
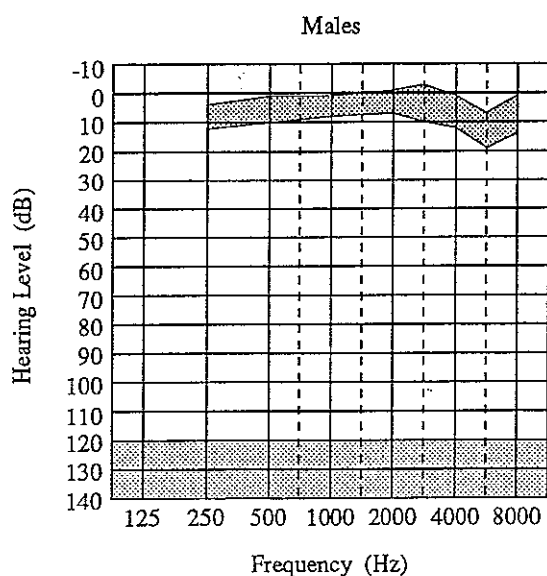


Table 3 continued

Hearing Threshold Levels for various fractions of typical British males and females.

Part B. Age 31-40

freq., kHz	0.25	0.5	1	2	3	4	6	8
males								
10%	1	-4	-2	-3	2	3	7	-1
25%	3	1	-1	1	5	8	14	4
50%	8	5	3	6	8	14	20	10
75%	11	8	4	9	19	22	31	19
90%	17	13	17	15	30	40	54	26
females								
10%	2	-1	-2	-2	-1	-2	8	1
25%	5	2	1	1	2	4	13	6
50%	8	6	4	5	7	8	20	12
75%	12	10	8	9	11	15	26	18
90%	16	13	12	12	18	24	34	25

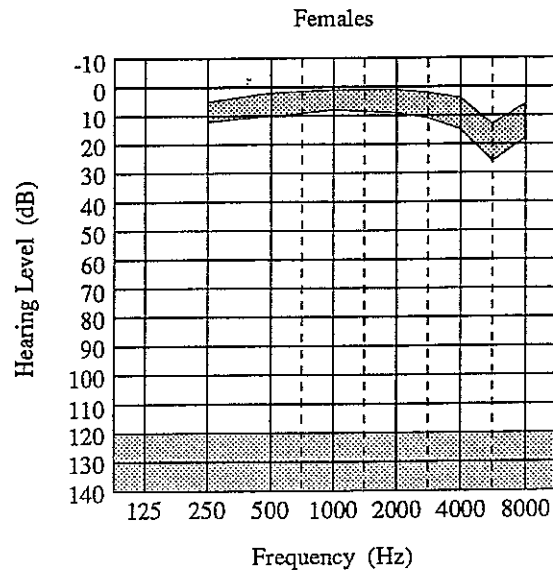
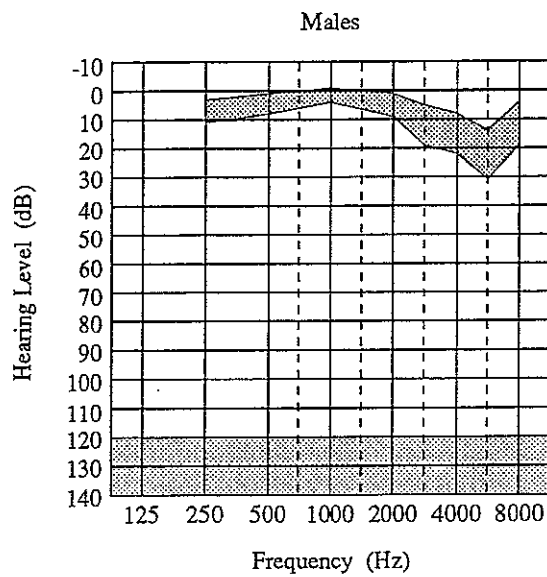


Table 3 continued

Hearing Threshold Levels for various fractions of typical British males and females.

Part C. Age 41-50

freq., kHz	0.25	0.5	1	2	3	4	6	8
males								
10%	4	1	1	0	2	3	15	9
25%	7	3	3	3	6	8	20	14
50%	10	6	6	7	11	13	27	19
75%	14	11	10	12	18	22	33	33
90%	16	15	14	17	27	31	37	41
females								
10%	2	0	0	1	1	3	10	6
25%	7	3	3	4	4	6	14	9
50%	10	7	7	8	10	13	22	15
75%	16	11	11	13	16	19	29	22
90%	19	17	15	19	20	25	38	40

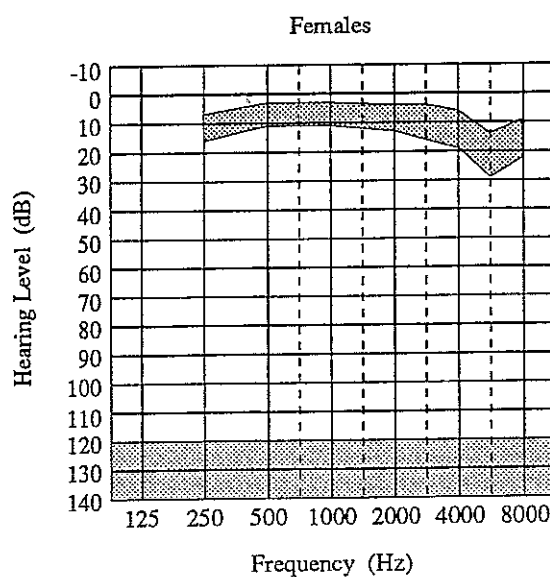
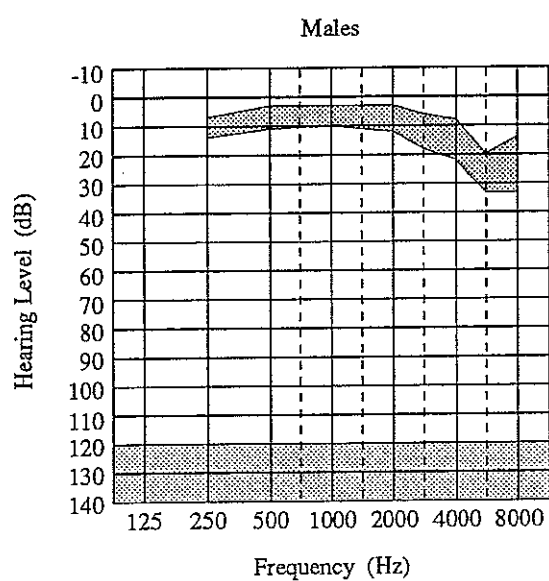


Table 3 continued

Hearing Threshold Levels for various fractions of typical British males and females.

Part D. Age 51-60

freq., kHz	0.25	0.5	1	2	3	4	6	8
males								
10%	5	0	3	1	7	11	17	12
25%	9	5	5	3	12	20	22	18
50%	15	10	9	10	17	25	37	32
75%	18	15	17	16	31	43	58	56
90%	22	22	22	33	45	56	71	73
females								
10%	6	3	2	2	1	8	17	9
25%	8	5	5	6	8	12	22	16
50%	12	10	10	12	14	18	28	28
75%	17	15	14	18	21	25	39	41
90%	22	23	20	25	30	37	48	52

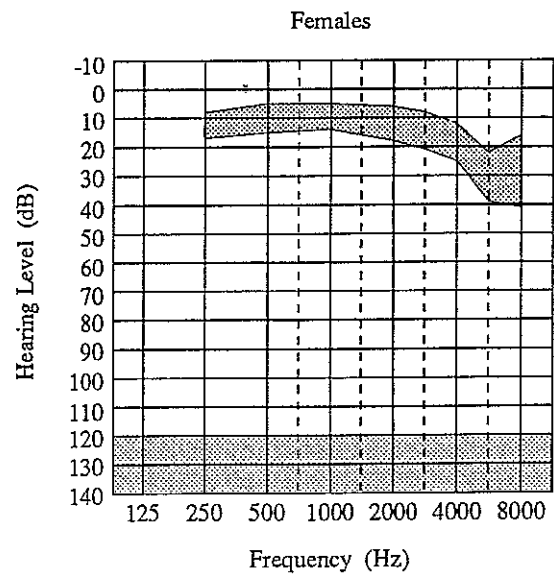
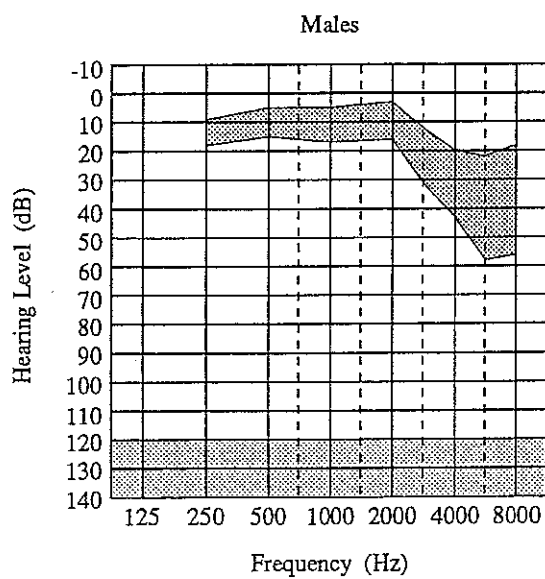
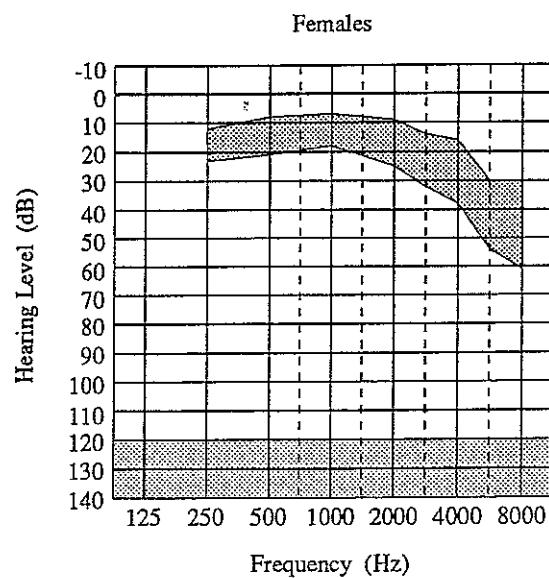
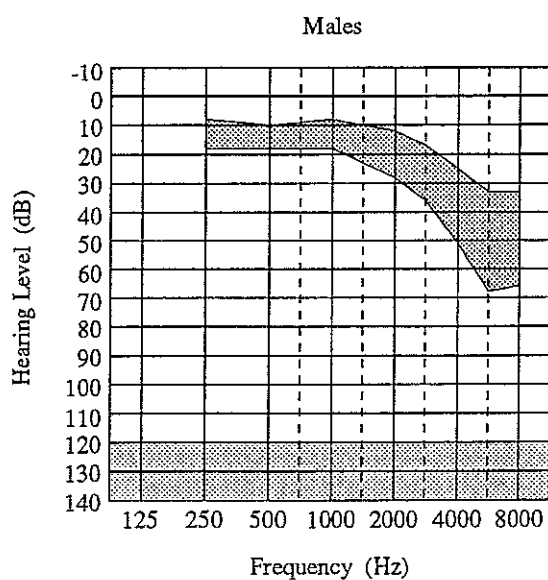


Table 3 concluded

Hearing Threshold Levels for various fractions of typical British males and females.

Part E. Age 61-70

freq., kHz	0.25	0.5	1	2	3	4	6	8
males								
10%	5	5	3	8	14	17	24	19
25%	8	10	8	12	17	25	33	33
50%	14	13	14	15	24	31	50	49
75%	18	18	18	28	36	51	68	66
90%	27	31	25	43	59	63	78	81
females								
10%	9	4	4	6	9	11	25	17
25%	12	8	7	9	14	16	30	30
50%	17	14	12	16	21	26	39	47
75%	23	21	18	25	32	38	54	61
90%	28	30	25	37	39	53	71	77



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