Results of the World's Fair Hearing Tests

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A hearing test for musical tones formed part of the Bell System exhibit at the New York and San Francisco Fairs, and the test records obtained have made possible a study of the hearing of a large group of the United States population. The variation of hearing acuity with age and sex is described in considerable detail. Hearing is also related in lesser degree to other factors, such as place of residence, economic status, and race, and these relations are discussed.

The data are applied to the United States population by indicating certain allowances which should be made for differences between the Fair groups and the population, particularly with respect to distribution of ages and economic status.

Accuracy of the test is discussed in relation to ability of visitors to understand the test procedure, disturbing effect of background noise, and calibration of the test equipment.

Certain results of the survey are expressed in terms of ear canal pressure and equivalent free field intensity, and on this basis a comparison is made with the results of other surveys of hearing.

A criterion is given for deciding how much hearing should vary from average before being considered abnormal. Application of this criterion indicates, in the case of children, a suggestive similarity between incidence of adenoid growth as reported in medical surveys and abnormal hearing for high frequency tones.

WITH the opening of the New York and San Francisco World's Fairs in 1939, an opportunity became available for a survey of hearing in a large group of the United States population. One of the Bell System Exhibits consisted of a hearing test whereby visitors could test their hearing for tones of musical pitch. At the end of the test, each visitor was asked to permit an attendant to make a photographic copy of his hearing test card so that a study of the records might be made. Before making the copy, the attendant indicated by a check mark whether the visitor was male or female, colored or white, and to which of the five age groups, 10–19, 20–29, 30–39, 40–49, or 50–59, she judged him to belong. In all, some 550,000 photographic records were obtained, and it is estimated that about 80 per cent of the visitors who tested their hearing for musical tones cooperated in the survey. A somewhat similar test for spoken words was also provided, but the survey was concerned principally with the results of the musical tones test.

The value and usefulness of such a large collection of records is dependent very directly upon the accuracy of the test. Therefore considerable attention was given to the calibration of the hearing test equipment and to the evaluation of factors which might affect the results of the test. There seems little doubt that the records accurately portray the hearing characteristics of that section of the population taking the tests.

One of the principal objectives of the study was to determine the hearing acuity and the prevalence of defective hearing in the United States population. The visitors who tested their hearing were not a representative sample of the population with respect to factors affecting hearing. Consequently a second objective was to determine the relation of hearing to such factors as age, sex, place of residence, economic status, etc. This information is necessary in order to apply the Fair data to the whole population or to specialized groups within the population.

It is believed that the two important factors, age and sex, have been satisfactorily evaluated. Information on other factors although less complete, is sufficient to justify many applications of the data. In other applications, it is necessary to make reservations and these are described in the text.

Description of the Test

The tests were made in sound-insulated rooms arranged to seat seven visitors, each partially screened from the others, as shown in Fig. 1. The test and suitable instructions were recorded on phonograph records and given through a telephone receiver which the visitor held to his ear. In the musical tone test a pure tone was sounded one, two, or three times, and the listener was instructed to write in a space on a form that was given him the number of times he heard the tone. For a given pitch, nine such sets of tones were sounded, each set fainter than the preceding one. When the tones became too faint to be heard, the listener could not write the number correctly, and thus a measure of his hearing acuity was obtained. This test was made with tones of five different frequencies in the following order: 440, 880, 1760, 3520, and 7040 cycles. A typical hearing test record is shown in Fig. 2.

The correct numbers, which appear in the spaces between the columns of Fig. 2, were printed on the back of the blanks in such a way that they would show through in these spaces when the blank was placed on a brightly illuminated glass shelf. The designations "normal or good," "slightly impaired" and "impaired," which show through

Fig. 1—Interior view of one of the hearing test booths.

opposite the eighth, fifth, and second steps respectively, were intended to give a qualitative indication of hearing acuity. Thus the visitor could correct his own test and obtain an indication of his hearing acuity for each frequency.

A scale of hearing acuity for expressing the results of the tests was set up, using as a zero or reference level the mean test score of men and women at the Fairs in the age group 20 to 29. Hearing acuity is expressed as a hearing loss in the usual way, i.e., the departure in db of a given test result from the reference level. As shown in a later section, this reference level gives an ear canal pressure which corre-

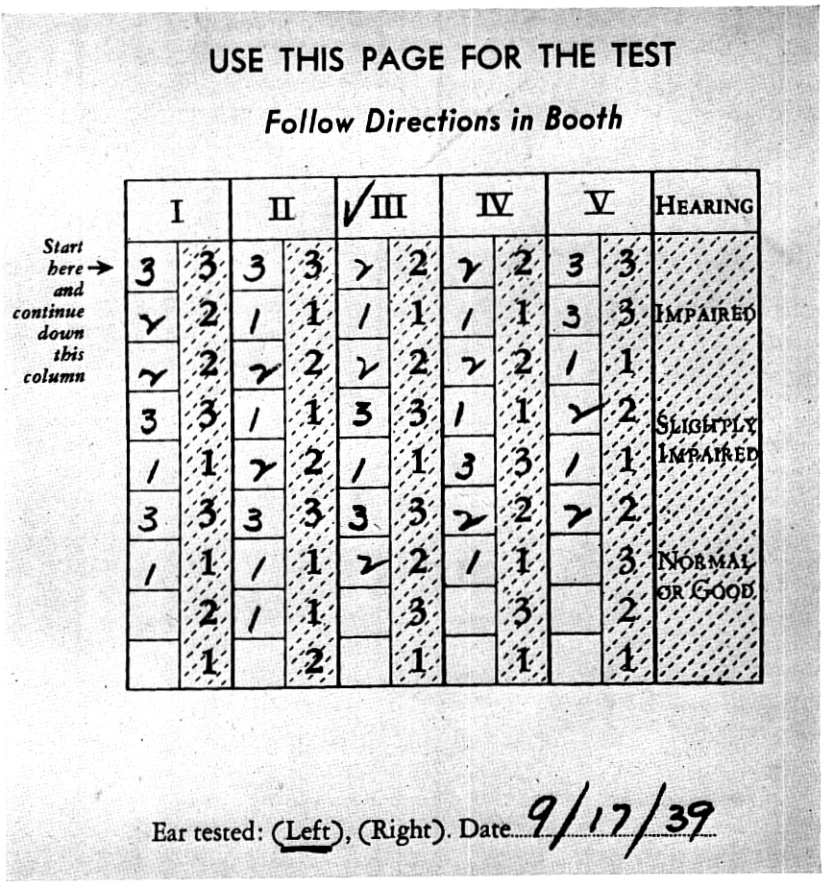

Fig. 2—Typical hearing test record as it would appear when illuminated from underneath.

sponds closely to that for zero hearing loss on the 2A Audiometer.[1] Hence hearing losses given here are comparable in magnitude with audiometric measurements.

The range of the test is shown in Table 1, which gives the hearing loss corresponding to each test step.[2] The range covered is 62 db in the first four columns and 48 db in the last.

[1] Some confusion has been occasioned by referring to the audiometer zero as normal hearing. Actually it is supposed to represent average normal hearing, where normal hearing refers to a range about the average value. If an individual has a hearing loss, his hearing is not necessarily abnormal. The amount of hearing loss which should be considered abnormal is discussed in a later section.

[2] The hearing loss values given in Table 1 correspond to the actual tone levels in the test. Throughout this paper it is assumed that the threshold of an individual lies between the last level at which he correctly records the number of tones and the first level at which he does not, and in computing mean values the loss is reckoned mid-way between these two levels.

TABLE 1

HEARING LOSS FOR EACH STEP IN THE MUSICAL TONE TEST

Column Frequency	I 440	II 880	III 1760	IV 3520	V 7040
Step 1	52*	52	52	46	33
2	42*	42	42	36	27
3	32	32	32	26	21
4	22	22	22	16	15
5	14	14	14	8	9
6	8	8	8	2	3
7	2	2	2	−4	−3
8	−4	−4	−4	−10	−9
9	−10	−10	−10	−16	−15

* These tones were used in the instructions for the test.

The voltage levels used at each frequency in the hearing test were selected so that the average young person would be able to hear the tones on the first six or seven steps, but would miss the last two or three.

RELATION OF HEARING TO AGE AND SEX

The relation of hearing loss to age and sex may be summarized by giving the average hearing loss. More detailed information may be obtained from tables giving the frequencies of occurrence of different amounts of hearing loss. In this section, both types of data are given for men and women separately, in five age ranges.

Trends in Average Hearing

Average hearing as indicated by the mean hearing loss for men and women in five different age groups is shown in Table 2. The number

TABLE 2

MEAN HEARING LOSS IN DB

Age Group		Frequency					Number of Tests
		440	880	1760	3520	7040	
Men	10–19	1.0	.3	−.3	−1.2	−.4	4132
	20–29	.0	−.2	−.1	2.0	1.5	3287
	30–39	1.4	1.3	2.3	8.2	7.7	3197
	40–49	3.7	4.5	7.0	17.7	16.8	4528
	50–59	6.8	7.7	12.1	25.6	24.0	1935
Women	10–19	.5	.2	−1.1	−4.4	−3.6	3417
	20–29	.0	.2	.1	−2.0	−1.5	4208
	30–39	2.6	2.6	2.9	2.4	4.8	3978
	40–49	6.0	5.8	6.7	7.8	11.9	4369
	50–59	10.3	9.8	11.0	13.8	19.7	2538

of tests used in obtaining the mean values is given in the right-hand column. For each age group, they were selected in a random manner from the New York and San Francisco tests, about two-thirds from New York and one-third from San Francisco.[3]

Certain trends in average hearing are evident in Table 2. On the average, both men and women show increasing hearing impairment with increasing age. For high-frequency tones, and especially at 3520 cycles, the effect is more pronounced in men than in women, but for

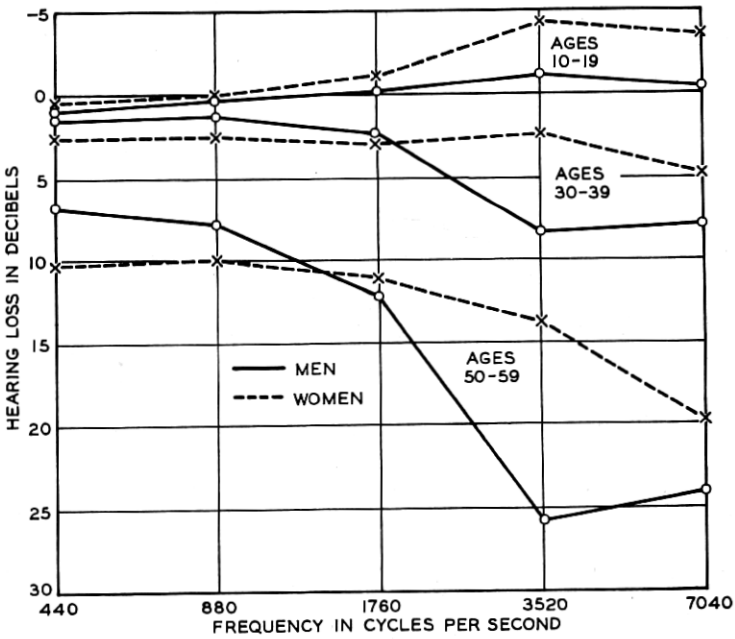

Fig. 3—Mean hearing loss in db for men and women in the youngest, middle, and oldest age groups.

low tones the opposite is true, although to a smaller degree. For the 1760-cycle tone there appears to be little difference between the hearing of men and women. These trends are shown in graphical form in Fig. 3, for the youngest, middle and oldest age groups.

At the lower frequencies, the hearing of the youngest group in Table 2 is slightly poorer than that of the next older group. It is

[3] Several sampling procedures were used, all based on selection of tests by some arbitrary rule, such as taking four tests in order then skipping twelve. In general, the same rule was used throughout a whole day's tests. The days selected were well scattered throughout the season, and week days and week-end days were used in the proper proportion. A larger sampling proportion was used for the older age groups, to make the groups in the sample more nearly equal in size.

believed that this is due principally to the greater difficulty of the younger children in understanding the test and writing their responses on the test blank.

TABLE 3

STANDARD DEVIATION OF HEARING LOSS IN DB

Age Group		Frequency				
		440	880	1760	3520	7040
Men	10–19	10.9	8.7	9.4	12.7	14.2
	20–29	8.5	7.1	8.7	13.8	14.5
	30–39	10.1	7.9	9.9	16.6	16.2
	40–49	11.6	11.0	13.4	19.3	17.0
	50–59	12.1	12.6	15.8	19.2	15.1
Women	10–19	10.6	8.6	8.6	9.4	11.6
	20–29	9.3	7.9	8.5	10.1	11.8
	30–39	11.1	9.9	10.2	12.1	13.8
	40–49	12.4	11.8	11.9	14.1	15.8
	50–59	14.0	14.0	13.9	16.2	15.4

Table 3 shows the standard deviations of the hearing losses for single tests. They range in magnitude from 7 to 20 db, and tend to increase with increasing age and tone frequency. An exception occurs for the 440-cycle tone where the values are mostly larger than for the 880-cycle tone. Since previous surveys have not shown a tendency for the standard deviation to increase below 880 cycles, it seems likely that the present increase occurred because the 440-cycle tone was the first one in the test, and initial unfamiliarity produced a greater scattering of the results. Carelessness in holding the receiver snugly against the ear would produce a similar scattering of results at this frequency.

The mean hearing losses and standard deviations for the older groups for the two high-frequency tones would be somewhat larger were it not for the restricted scale of the test. At 3520 cycles the range from zero is only 46 db, and at 7040 cycles, only 33 db. In computing means and standard deviations all results lying beyond the range of the test were grouped one test step beyond the extreme value included in the test.

Distribution of Hearing Loss

In addition to giving the trends in average hearing, the hearing test scores afford a means of determining the frequency of occurrence of different amounts of hearing loss. A convenient method of presenting the occurrence rates of different degrees of deafness is by means of curves or tables showing cumulative distributions. Table 4 shows

TABLE 4

DISTRIBUTION OF HEARING LOSS

Percentage of tests failing to show a correct response at the test step indicated, based on 23,320 tests from the N. Y. Fair and 12,269 tests from the S. F. Fair.

Frequency	Test Step	Hearing Loss	Men, Age Group					Women, Age Group				
			10–19	20–29	30–39	40–49	50–59	10–19	20–29	30–39	40–49	50–59
440	1	52*	—	—	—	—	—	—	—	—	—	—
	2	42*	—	—	—	—	—	—	—	—	—	—
	3	32	2.7	1.2	2.5	4.1	5.4	2.5	1.5	3.5	5.4	9.9
	4	22	4.6	2.1	4.2	7.1	9.8	4.1	3.0	6.1	10.7	17.9
	5	14	9.2	5.3	8.3	13.9	21.2	8.4	6.6	11.8	20.9	33.5
	6	8	16.0	11.0	14.7	22.3	32.1	15.2	12.1	19.4	30.9	44.3
	7	2	40.0	32.3	38.7	46.7	60.9	37.7	33.5	43.3	56.2	68.9
	8	−4	67.1	67.9	71.3	77.6	85.7	64.7	65.1	72.9	81.8	88.1
	9	−10	86.2	92.2	93.6	95.1	97.8	84.9	90.7	94.0	96.2	98.0
880	1	52	.4	.1	.1	.7	1.4	.4	.2	.8	1.2	1.9
	2	42	.7	.2	.4	1.8	3.2	.6	.5	1.4	2.6	5.3
	3	32	.9	.6	.9	3.2	5.4	1.0	1.1	2.1	4.1	7.6
	4	22	2.1	1.3	2.3	6.8	12.0	2.2	2.1	4.4	8.7	16.1
	5	14	4.9	2.9	5.5	13.5	21.6	4.6	4.3	8.5	16.0	27.1
	6	8	10.3	7.4	11.7	23.0	33.6	9.3	8.2	15.3	26.4	40.9
	7	2	34.3	30.2	37.5	49.3	62.3	32.5	29.9	40.8	55.1	68.0
	8	−4	77.5	76.1	81.8	87.3	92.3	77.4	78.1	84.0	89.6	93.3
	9	−10	88.9	93.8	96.2	97.6	98.9	90.6	95.0	97.4	98.2	98.8
1760	1	52	.5	.2	.4	1.7	4.3	.2	.2	.6	.8	1.6
	2	42	.6	.4	.7	2.9	6.3	.5	.4	.9	1.8	3.9
	3	32	1.0	.7	1.5	5.6	11.0	.8	.8	2.1	3.8	8.3
	4	22	1.9	1.4	3.5	11.0	19.5	1.4	1.9	4.4	8.8	16.6
	5	14	5.0	5.7	9.5	20.3	33.4	3.8	4.9	9.4	19.5	31.9
	6	8	11.3	11.5	18.3	32.9	47.8	7.9	10.7	17.8	32.9	47.5
	7	2	31.5	31.8	40.3	55.6	69.1	26.7	30.7	43.0	58.7	70.4
	8	−4	63.5	63.6	74.6	82.8	90.2	60.1	66.4	77.2	85.1	91.2
	9	−10	85.1	89.4	93.3	95.6	97.9	85.9	91.0	94.5	97.3	97.8
3520	1	46	1.8	2.5	5.8	15.3	25.6	.2	.6	1.5	3.0	6.7
	2	36	2.3	3.9	8.8	20.4	33.8	.4	1.1	2.3	5.0	10.7
	3	26	3.8	6.3	13.6	29.9	45.8	1.0	1.9	4.7	9.6	19.8
	4	16	7.8	11.7	23.5	44.8	61.7	2.9	4.5	10.4	21.9	36.2
	5	8	13.3	20.2	36.1	60.1	75.5	6.6	10.2	21.2	37.7	54.7
	6	2	26.7	35.7	54.0	73.9	86.8	16.4	21.9	38.0	56.2	72.3
	7	−4	54.5	64.1	76.9	88.8	95.3	45.0	52.5	68.6	81.7	89.7
	8	−10	78.4	85.8	93.2	97.0	99.2	71.8	81.2	91.3	95.9	98.0
	9	−16	90.6	95.6	98.1	98.9	99.7	89.0	95.5	98.2	98.9	99.3
7040	1	33	6.3	7.8	16.1	35.0	53.1	1.6	2.7	8.4	20.1	38.3
	2	27	7.1	8.9	18.1	37.5	56.6	2.0	3.3	9.6	22.7	41.1
	3	21	8.7	10.7	20.8	41.8	60.8	3.0	4.4	11.9	27.2	45.9
	4	15	13.2	15.3	28.6	50.9	70.5	6.2	7.9	19.1	38.0	57.7
	5	9	20.6	23.8	38.6	61.7	78.4	13.8	15.7	31.1	50.7	70.2
	6	3	32.5	35.7	52.4	72.6	86.4	24.1	28.2	47.2	64.9	82.1
	7	−3	49.4	54.7	70.4	85.0	94.0	41.3	49.3	67.7	81.3	92.6
	8	−9	70.2	75.6	85.0	93.8	97.5	64.0	72.3	86.0	92.7	97.6
	9	−15	82.7	88.1	94.5	97.6	98.9	80.0	87.9	95.1	97.5	99.1
No. of Tests			4132	3287	3197	4528	1935	3417	4208	3978	4369	2538

* These tones were used for the instructions for the test.

such distributions for the 35,589 test scores that were used in calculating the mean hearing loss values of Table 2. It is arranged to show, for each of the five tones, the cumulative distributions separately for men and women in the five age ranges. It gives the percentage of tests failing to show a correct response at the test step indicated, or the percentage of individuals having a greater hearing loss than that corresponding to the indicated step. For example, the table shows that only 0.7 per cent of the men in the 20–29 age group have hearing losses greater than 32 db for a 1760-cycle tone, while 11 per cent of those in the 50–59 group have this much loss.

Zero hearing loss falls between steps 7 and 8 for the first three tones, and between steps 6 and 7 for the last two tones. The last step corresponds to very good hearing, and individuals able to hear this step have hearing acuities at least 10 db better than average. Some 10 or 15 per cent of the youngest age group, but only 1 or 2 per cent of the oldest group, were able to hear the tones on the last step. For the tone of lowest frequency, there were seven young persons for every older person who could hear the last step, but at 7040 cycles, there were 18 young persons for every such older person.

The tabular data for the age groups 20–29 and 50–59 are shown graphically in Fig. 4 for four of the tones, beginning at 880 cycles.[4] The curves are cumulative distributions and the ordinate gives the percentage of individuals having hearing losses greater than the value indicated by the abscissa.[5] At 880 cycles hearing losses in excess of a given amount tend to be more prevalent among women than among men. At 1760 cycles the distribution curves for men and women are much the same. At the two higher frequencies, the prevalence of deafness in excess of a given amount is greater among men than among women.

A hearing loss of 25 db at frequencies up to 1760 cycles begins to be a handicap. The individual will usually be aware of such an impairment, and will experience difficulty in understanding speech under conditions of public address, such as in the church or theater or around the conference or dinner table. The distribution curves show that only about 1.5 per cent of the young people taking the test, or three out of 200, have a hearing loss of 25 db or more for tones of these frequencies. In the oldest age range almost ten times as many, or every seventh person, shows this much impairment.

[4] The distributions for 880 cycles may be used for 440 cycles as well, it being assumed that the small difference shown in Table 4 is due to practice.

[5] The ordinates are shown on an arithmetic probability scale, which has the property that a normal distribution plots as a straight line whose slope is proportional to the standard deviation of the distribution. It is convenient because it shows the small values more accurately and because on this scale the standard errors of the ordinates are approximately equal in all parts of the range.

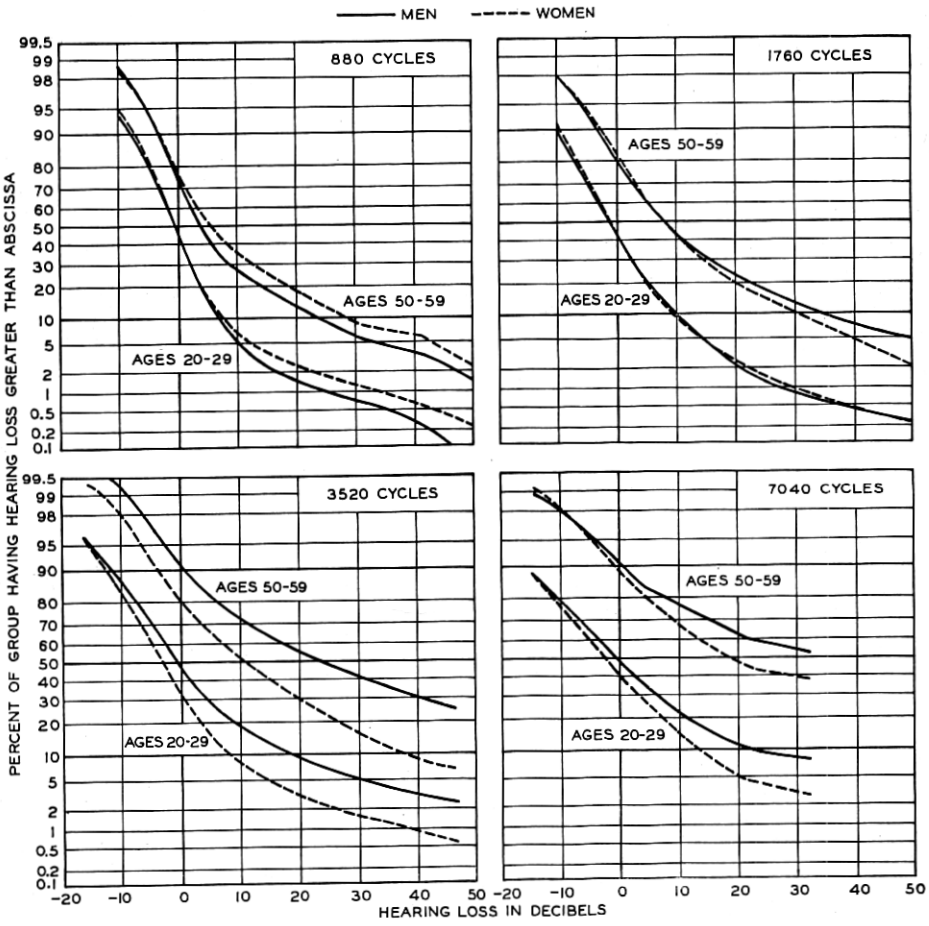

Fig. 4—Percentage of people in a given age and sex group having a hearing loss greater than any given value.

A hearing loss of 45 db for frequencies up to 1760 cycles will usually make it difficult to hear direct conversation even when the speaker is about two or three feet away. Individuals with this much loss usually need some sort of hearing aid. Table 5 gives the percentages of various groups that have losses in excess of 25 db and 45 db at the various frequencies.[4]

Acuity for the two high-frequency tones is less important than for the low tones for understanding speech, so that a loss for the high tones is not such a serious handicap. High-tone deafness is of particular interest, however, to the extent that it is indicative of a pro-

TABLE 5

PERCENTAGE OF TESTS WITH HEARING LOSS GREATER THAN 25 AND 45 DB.

Age Group		25 db Loss, Frequency				45 db Loss, Frequency		
		440, 880	1760	3520	7040	440, 880	1760	3520
10–19	Men	1.7	1.6	4.5	8.0	.6	.6	1.8
	Women	1.8	1.2	1.2	2.4	.6	.4	.3
20–29	Men	1.1	1.2	7.0	9.5	.1	.3	2.7
	Women	1.8	1.6	2.2	3.5	.4	.3	.7
30–39	Men	1.8	3.5	15.0	19.0	.3	.6	6.0
	Women	3.5	3.5	5.5	10.0	1.2	.8	1.6
40–49	Men	5.5	9.5	32.0	39.0	1.4	2.6	16.0
	Women	7.0	7.0	11.0	24.0	2.1	1.5	3.0
50–59	Men	9.5	17.0	48.0	58.0	2.6	6.0	27.0
	Women	13.0	14.0	22.0	43.0	4.0	3.0	7.0

gressive condition which may later involve tones of lower frequency. It is striking to note that, of the people taking the hearing test at the World's Fairs, some 6 per cent in the 20–29 year age range showed a hearing loss in excess of 25 db for the 7040 cycle tone. In the oldest age range half of the people showed such a loss. It is likely that an even larger proportion would be found in a random sample of the population, for, as will be discussed in a subsequent section, it is believed that the people taking the test at the Fair represent an economic status that is average or better, and there are indications of a greater prevalence of hearing defects in the lower economic groups.

The Estimation of Age

As previously indicated, estimates were relied upon to furnish information on the ages of the visitors taking the hearing test. The attendant making these estimates was changed every hour or so, about fifty being used in the course of a week at the New York Fair. In order to determine the accuracy of the estimates, 267 test blanks of members of Bell Telephone Laboratories families were examined and the real age compared with the estimated age indicated on the blank. In most cases the attendant who made the estimate was not aware that the individual was a member of the Bell System. It was found that 62 per cent of the real ages were within the estimated 10 year age group, while 83 per cent were not more than 3 years outside of the group and 96 per cent were not more than 8 years outside of the group. There was a general tendency to estimate high for young people and low for older people.

The average real age in any estimated age group depends on the distribution of ages within the group, the amount of random error involved in making the estimates, and any consistent tendency to estimate high or low. The distribution of estimated ages at the two Fairs is shown in Table 6, together with the age distribution of people

TABLE 6

PERCENTAGE OF INDIVIDUALS OVER 10 YEARS OF AGE FALLING IN VARIOUS AGE GROUPS ACCORDING TO ESTIMATES AT THE TWO FAIRS, AND FROM THE 1930 U. S. CENSUS

Age Group	New York	San Francisco	United States Population
10–19	34	27	24
20–29	25	23	21
30–39	23	23	19
40–49	14	16	15
Over 50	4	11	21
Total	100	100	100

over 10 years of age in the U. S. population (1930 census). At New York, the youngest group was considerably larger than the corresponding group in the population while the oldest group was very much smaller. The same tendency, but to a lesser degree, is seen in the San Francisco distribution. The distribution of ages fluctuated greatly on different days of the week and at different seasons. The table is based on counts on about 35 days at each Fair, well scattered through the season.

From the results obtained with the control group described above and the age distributions of Table 6, the average real age in each age group was judged to be as follows:

Age Group	10–19	20–29	30–39	40–49	50–59
Average real age	15	23	33	44	56

These values should be reliable to the extent that it is reasonable to assume that the accuracy of the age estimates of the control group was representative of the whole group at each Fair. The oldest group, which is designated 50–59 throughout this paper, included that range at New York, but at San Francisco included all persons over 50. Because of this the average real age in this group is judged to be 54 at New York and 60 at San Francisco. The value in the table is the weighted average of these two figures.

Relation of Hearing to Other Factors

In the preceding section it was shown that hearing acuity varies to quite an important extent with the age and sex of the group. The next problem is to identify any other factors to which hearing acuity is related to a significant degree. A sensitive method of determining whether such factors exist is provided by the control chart technique developed in connection with the statistical control of manufactured product.[6] When the hearing tests results, corrected for age and sex differences, were plotted on a control chart there was very definite evidence of lack of statistical control. This indicates that one or more factors exist to which hearing is significantly related, and experience in other fields in which control chart technique has been applied suggests an excellent chance of being able to identify these factors. The most straightforward procedure would have been to make a careful study of those individuals whose tests fell outside of the control chart limit and discover the factors responsible for the abnormal scores. This was not feasible at the Fairs, and other less direct methods were used as described below.

In the discussion which follows, a judgment must often be made as to whether an apparent relation between hearing and some factor under discussion is significant. The customary formula for the significance of a mean

$$\sigma_m = \frac{\sigma}{\sqrt{n}},$$

where σ_m is the standard deviation of the mean of a group of n observations and σ is the standard deviation of a single observation, has not been used, because modern statistical theory shows that this relation is valid only for data which are in a state of statistical control. The data of this section do not meet this requirement, and attempts to use the above relation as the sole test of significance are often misleading. The judgments which are expressed as to the significance of a relation are based upon the consistency with which the relation appears when the data are broken up into small groups. Space does not permit showing all the evidence on which these judgments are based, but the summaries which are presented indicate the magnitude of such relations as are judged to exist.

Place of Residence

Data from the New York and San Francisco Fairs were compared to discover any differences which might be attributed to sectional

[6] W. A. Shewhart, "Statistical Method from the Viewpoint of Quality Control" (Grad. School, U. S. Dept. of Agriculture, 1939).

TABLE 7

DIFFERENCE IN MEAN HEARING LOSS AT NEW YORK AND SAN FRANCISCO

		Frequency					No. of Tests	
		440	880	1760	3520	7040	N. Y.	S. F.
Men	10–19	.8	.0	.0	2.4	3.6	2839	1293
	20–29	.6	−.3	−.1	1.8	3.6	2219	1068
	30–39	.8	−.4	−.4	2.6	3.1	2193	1004
	40–49	−.5	−.8	.0	4.0	2.7	3171	1357
	Aver.	.4	−.4	−.1	2.7	3.2		
Women	10–19	.0	−.8	−1.0	−.2	.5	2172	1245
	20–29	.3	−.6	−.9	−.2	1.8	2848	1360
	30–39	.7	−.5	−.9	.2	2.3	2733	1245
	40–49	.6	−.2	−.1	.4	.8	3119	1250
	Aver.	.4	−.5	−.7	.0	1.4		

differences in hearing acuity. Table 7 gives the difference in mean hearing loss between corresponding age groups at New York and San Francisco for the age groups below 50. A positive difference indicates greater hearing loss at San Francisco.

At the three lower frequencies, the differences are insignificant. The differences at the higher frequencies are not large enough to be conclusive evidence of a sectional difference in hearing, but it seems quite probable that the men taking the test at San Francisco were, on the average, some three decibels less acute than those at New York for the frequencies 3520 and 7040. No important differences in standard deviation or general form of the distribution of hearing loss were noted in comparing the two Fairs.

For approximately a week at each Fair a question was printed on each hearing test blank asking whether the visitor lived (*a*) in the city where the Fair was held, (*b*) within commuting distance, or (*c*) beyond commuting distance. From the replies to these questions it was found that roughly one-quarter of the visitors at each Fair lived in the city, and another quarter within commuting distance. The remaining one-half were probably well scattered. The test results were analyzed in relation to place of residence. Most of the differences in mean hearing loss were so small that they could easily be attributed to sampling variations. Only one of the comparisons among the various groups showed differences sufficiently large and consistent to be significant. Women from New York City had greater hearing loss at all frequencies than women from the commuting area or beyond, as shown in Table 8. The groups compared number 600 and 1400 respectively. The differences did not show any trend with

age. The table gives the average difference between corresponding age groups in the age range from 10 to 49. A similar difference was not found among the men nor among the corresponding groups at San Francisco.

TABLE 8

Frequency	440	880	1760	3520	7040
Hearing Loss Difference	1.4	2.7	2.2	1.6	2.6

The differences just discussed are small enough so that the average hearing values computed from all the data will not be critically dependent on the weight assigned to the various geographical groups. On the other hand, some of the differences are large enough to suggest that a more efficient segregation into geographical groups, taking account of past as well as present place of residence, might uncover some substantial differences in hearing.

Personal Characteristics

An attempt was made to determine the relation to hearing acuity of several such factors as economic status, intelligence, and general appearance. This was done by observing individuals at the New York Fair as they submitted their test blanks for the photographic record. Some ten or fifteen seconds of observation were usually available, and the individual was classed as below, average, or above in respect to the characteristic being studied. Although separate estimates were attempted for each of the three characteristics named above, it was concluded that in each case the same thing was being estimated, namely general personal appearance. Accordingly all the data were combined. Table 9 summarizes the findings. Each figure is the mean of the mean hearing losses for the age groups below 50.

TABLE 9

VARIATION OF MEAN HEARING LOSS WITH PERSONAL APPEARANCE

	Frequency					No. of Tests
	440	880	1760	3520	7040	
Men—Below	4.3	2.4	1.8	4.4	5.7	95
Average	1.5	1.5	1.9	8.2	7.6	560
Above	−1.2	0.5	0.8	6.0	2.0	184
Women—Below	4.4	3.2	3.8	4.3	6.7	52
Average	2.2	2.7	2.5	2.4	3.6	658
Above	0.6	1.4	1.7	0.8	2.3	259

The differences shown suggest a relation between hearing acuity and general personal appearance, although the evidence is not conclusive. In each of the ten comparisons given in the table, there is an increase in hearing acuity in going from average to above average and in nine out of ten there is an increase in going from below average to above average. Personal appearance is somewhat related to economic status and intelligence. A more accurate index of these might show a more striking relation with hearing acuity.

Race

The number of tests of negroes tabulated thus far is too small to give a satisfactory picture of the hearing trends among them. However, there is no indication of substantial departure from the results reported by Bunch and Raiford,[7] who determined that the hearing of negro men and women is similar to that of white women.

Awareness of Hearing Impairment

People whose hearing is impaired are often quite sensitive, and it seems possible that some may have avoided the hearing test for this reason. On the other hand, a person with impaired hearing might be especially attracted by the opportunity to measure it. Whether the data show too high or too low an incidence of hearing impairment depends on which of these factors predominates. This is a possibility for bias that is present in any survey where participation is voluntary. No satisfactory method of evaluating it has been discovered. However, the following discussion is intended to give some idea of the magnitude of the error which may be involved.

Since a person is scarcely aware of a hearing loss of less than 25 db, it may be assumed that neither of these factors would affect the distributions below that value. For greater losses some effect may be expected, gradually increasing so that above 40 db the possibility of a substantial bias in the distributions must be considered. The shift of the mean values of hearing loss is probably not very pronounced. For example, Table 10 shows the shift in mean hearing loss at 1760

TABLE 10

Age	20–29	30–39	40–49	50–59
Men	0.4 db	0.7 db	2.6 db	4.8 db
Women	0.4	0.9	1.6	2.9

[7] C. C. Bunch and T. S. Raiford, "Race and Sex Variations in Auditory Acuity," *Arch. of Otolaryng.*, **13**: 423–434 (1931).

cycles which results when the number of cases of hearing loss over 42 db is tripled. Eliminating all cases over 42 db would produce about half as much shift in the opposite direction. However, the form of the distribution curves for large values of hearing loss may be substantially in error.

Hearing losses at 3520 and 7040 cycles are much more common, but are not likely to be noticed except when accompanied by a loss at a lower frequency. Consequently, the biasing effect of a selective process based on awareness of hearing loss is less pronounced at these frequencies.

Right and Left Ears

The physical arrangements at the Fairs made it awkward for a right-handed person to test his right ear. As a result, about 80 per cent of the recorded tests were for the left ear. No appreciable difference was found between the test results for right and left ears. However, this may be taken as only a rough indication of equality between the ears, in view of the differences in test conditions for the two ears.

Time of Day

Data from each Fair were studied to determine whether there was any significant variation in hearing with time of day. Table 11, which gives values of mean hearing loss covering a period of about two weeks at the San Francisco Fair is typical.

TABLE 11

VARIATION OF MEAN HEARING LOSS WITH TIME OF DAY

	Frequency					No. of Tests
	440	880	1760	3520	7040	
Morning (9–1:30)	1.0	1.2	1.9	3.5	3.5	1285
Afternoon (1:30–5:30)	2.1	1.4	2.3	3.3	4.6	1637
Evening (5:30–10)	1.4	1.6	2.3	3.4	4.4	1511

The figures given are averages of several age groups. An apparent slight trend to poorer hearing in the afternoon is probably not significant, because detailed study of this and other data showed that this trend was not consistent. It was concluded that there were no trends of hearing acuity with time of day in any age group of sufficient magnitude to be revealed by the survey.

Variation Over Longer Periods

A comparison of data obtained at the New York Fair during a period early in the summer and another period early in the fall is given in Table 12. This table gives the difference in mean hearing loss for the two periods for the various age and sex groups. A positive difference indicates greater hearing loss in the later period.

TABLE 12

DIFFERENCE BETWEEN MEAN HEARING LOSSES DETERMINED DURING TWO DIFFERENT PERIODS

Ages		Frequency					No. of Tests
		440	880	1760	3520	7040	
Men	10–19	.4	.2	.0	.7	.6	1509, 1330
	20–29	−.7	−.8	−.6	.9	−.2	1110, 1109
	30–39	−1.0	−.6	.5	1.1	1.4	1053, 1140
	40–49	.2	.2	.2	1.4	1.1	1802, 1369
	50–59	1.8	1.9	2.6	5.0	3.1	432, 511
Women	10–19	−1.4	.0	−.4	−.7	−.4	1028, 1144
	20–29	−1.0	.1	.5	.9	.6	1645, 1203
	30–39	−.7	.2	.3	.1	1.0	1363, 1370
	40–49	−.5	−.3	−.3	.6	1.0	1722, 1397
	50–59	.3	1.0	1.3	1.8	1.1	440, 643
Average	10–49	−.6	−.1	.0	.6	.6	

The average difference is rather small, and may be taken to indicate good stability on the part of the test equipment and lack of any pronounced seasonal trends in hearing over this interval.

DISTRIBUTION OF HEARING ACUITY IN THE UNITED STATES POPULATION

The tests at the two Fairs constitute a large cross section of the United States population. It is not a representative cross section in certain respects, the most important of which are described below. It is believed that by taking into consideration the limitations mentioned below an estimate of the distribution of hearing acuity in the United States population can be obtained which is sufficiently accurate for most practical purposes.

The two Fairs taken together probably represent a good geographical cross section of the country, except that areas near the Fairs were too heavily represented. However, since no pronounced differences in hearing were found for those living near the Fairs, the geographical sampling may be regarded as fairly satisfactory. Although it is quite

possible that sections might be found in which hearing differed markedly from the Fair values, it is unlikely that such areas would be extensive enough to affect the overall result.

With regard to economic status, intelligence, and amount of education, the Fair groups were judged to be somewhat above average, and probably representative of the upper two-thirds or three-quarters of the population. If hearing is related to such factors, as seems probable, the hearing of the population is not quite so good as indicated by the Fair tests.

The portion of the distribution curves relating to large hearing losses at the three lower frequencies must be accepted with reservations on account of the possible biasing effect of awareness of hearing impairment, as discussed in the preceding section. However, the curves should be reliable below about 35 db loss, and the curves for the two highest frequencies should be reliable throughout the test range.

The distribution of ages at the Fairs was quite different from that in the population. The first step in allowing for that difference was made by recombining the distributions of hearing loss for various age and sex groups shown in Table 4, weighting each according to the size of the group in the population. The resulting distributions are shown in Fig. 5, and apply to the age range 10–59 years.[4]

In a similar manner, the figures in Table 5 for the incidence of hearing loss of 25 db or more were weighted according to the size of the groups and combined, leading to the values given in the first line of Table 13, for the age range 10–59. This process can be extended to include the whole age range as follows. It is assumed that the incidence for ages under 10 is the same as in the 10–19 group. This may not be strictly true, but is a sufficiently good approximation for this purpose. For ages above 60 a minimum estimate was obtained by assuming that the incidence of hearing loss is the same as in the 50–59 group, and a maximum estimate by assuming 100 per cent incidence above age 60. The actual value may be expected to be somewhere between these limits, which are shown in Table 13.

Except for the reservations stated in the first four paragraphs of this section, it is believed that the data of Figs. 3, 4, and 5 and Tables 2, 3, 4, 5, and 13 should apply fairly closely to the U. S. population as a whole. They may also be applied to groups in the population who are not specialized in regard to any factor related to hearing. It would be unsafe to apply them to a group of very low or unusually high economic status, college graduates, unskilled laborers, foreign groups,

[4] Loc. cit.

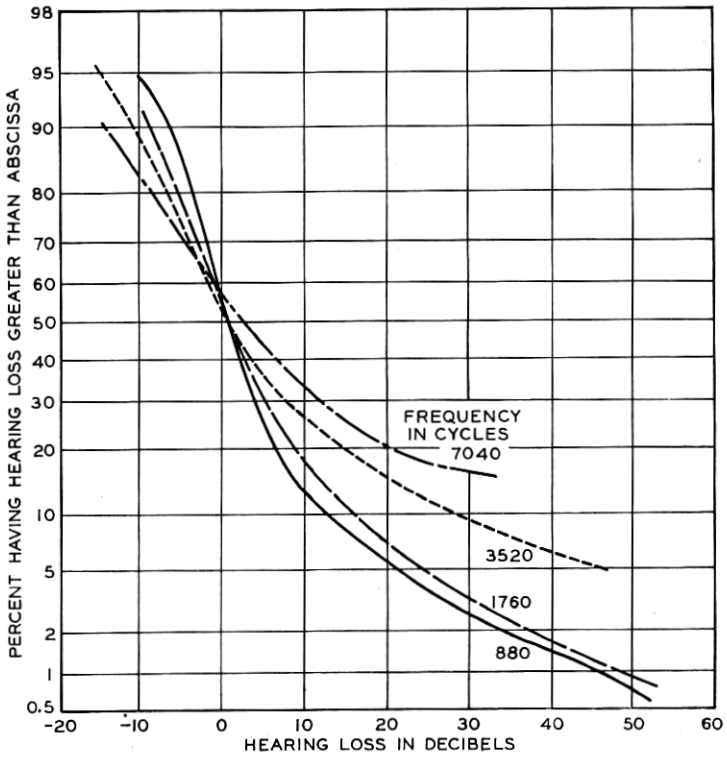

Fig. 5—Percentage of people, both men and women, in the age range 10–59 having a hearing loss greater than any given value.

TABLE 13

PERCENTAGE OF PEOPLE HAVING HEARING LOSS OF 25 DB OR MORE

		Frequency			
		440, 880	1760	3520	7040
Ages 10–59		3.8	4.5	12	18
All ages	Minimum	4	5	12	18
	Maximum	11	12	18	22

etc. without further knowledge of the relation between hearing and the factor in which the group was unusual.

ACCURACY OF THE HEARING TEST

The participation of the visitors in the test was entirely voluntary, and nothing is known from the test records concerning their reasons

for taking the test. Observation indicated that the great majority of people took the test seriously, and made a conscientious attempt to test their hearing.

It was noticed that a very small percentage of the people, mostly in the youngest age group, altered their scores by filling in all of the missing numbers before having them photographed, thus giving a false appearance of a perfect test. Some of these were detected from the differences in writing, and were eliminated from the tabulations, but others were probably included. It is believed that the number of false scores included was too small to affect the hearing loss distributions appreciably.

Some people undoubtedly secured poor scores in the test on account of failure to understand the test, interruptions, or other causes not connected with hearing. A study of this factor was made by observing about 1200 tests, picked at random, and interviewing all those who failed to fill in more than three squares of their test blanks. About 1.5 per cent failed the test in this sense, and were subsequently interviewed and watched to see if they permitted their test scores to be photographed. The interview revealed that about two-thirds of this group failed the test because they were definitely hard of hearing. Also, as it happened, about two-thirds of them submitted their test scores to be photographed, so that the number of recorded failures tended to be the same as the number that were actually hard of hearing.

The noise conditions under which the tests were given were quite favorable. The exhibit building was quiet due to the generous use of sound absorbent walls and carpeted floors. Parts of the building containing air-conditioning and other machinery were constructed on a separate foundation from the part containing the hearing test booths. The booths were carefully insulated, the attenuation of the walls to air borne sounds being 30 db or more over a wide frequency range. Additional isolation was provided by a glass partition between the booths and the lobby. Noise in the booths from external sources was nearly inaudible, and it is probable that most of the distributing noise was caused by the people participating in the test.

Sound level meter measurements with flat weighting were made in a booth where noise from external sources was judged to be most objectionable, and while regular tests were in progress. The average and maximum readings are given in Table 14. After making allowance for the attenuation of the telephone receiver covering the ear, the masking computed for the average noise level was less than 5 db at 440 cycles and zero at the higher frequencies. The masking of a

TABLE 14

SOUND LEVEL METER READINGS, WITH FLAT WEIGHTING, IN DB ABOVE .0002 DYNE PER SQUARE CENTIMETER

Frequency Band	100–300	300–500	700–900
Average reading	43	<25	≪25
Maximum reading	50	35	26

steady noise equal in magnitude to the maximum noise levels was computed to be 11 db at 440 cycles, 3 db at 880 cycles, and zero at higher frequencies.[8] The interpretation of these results is in some doubt because the people in the booths tended to be more quiet when the test level approached threshold, and also because the disturbing effect of sounds of irregular character may not be properly indicated by masking computations based on experiments with steady sounds. Accordingly a more direct method of evaluating the disturbing effect of noise was tried.

Members of Bell Telephone Laboratories who had taken the test at the Fair under routine conditions at various times during the season were retested at the Laboratories after the Fair closed. The same equipment and procedure were used, except that only one person was tested at a time under conditions free from any disturbing noise except that created by the observer himself. On the average, the tests indicated more acute hearing during the retest at the Laboratories, particularly at the low frequencies. The average shift was 2.9 db at 440 cycles, 1.4 db at 880 cycles, 1.1 db at 1760 cycles, and negligible at the higher frequencies. Since the test at the Laboratories was given last in every case these shifts may have been partly due to improvement with practice. However, they serve to set an upper limit to the average disturbing effect of noise. This comparison is based on tests of 150 ears of 106 people, whose average age was 39 and whose average hearing acuity was somewhat better than an equivalent age group at the Fair.

The equipment for the tones hearing tests consisted of eight machines at New York and two at San Francisco. These machines were maintained in an equipment room some distance from the test booths, one machine being connected to each booth. Each machine consisted of a phonograph reproducer, amplifier, attenuation network, and seven

[8] These values of masking apply to an ideal observer having a threshold approximating the minimum audible pressure curve of Fig. 6. Since a great majority of observers at the Fairs had higher thresholds, the masking would be correspondingly less for them.

telephone receivers in parallel on the output.[9] Vertical cut phonograph records contained instructions for the test and the tones used in the test. To insure a favorable ratio of signal to record and amplifier noise throughout the test, the test tones were recorded at constant level, and the desired level changes were obtained by changes in the attenuation network made in synchronism with the turntable.

Output of each phonograph reproducer and amplifier was checked daily, and held within limits which varied from ± 0.5 db at the lowest frequency to ± 2 db at the highest frequency. Performance of the attenuation networks was determined twice during the season by careful measurements of voltage at each test level and each frequency. They were found to give the expected values of attenuation within 1 db at all levels. The efficiency of each receiver was measured on a rigid closed coupler. The standard deviation of all the receivers used was about 1 db at the lower frequencies and 3 db at 7040 cycles. Check measurements were made at intervals of about one month on each receiver. The mean response of all the receivers varied by less than 1 db during the season. The ten machines were alike in output (at the test level nearest the reference level) within ± 1.0 db at the three lower frequencies and within ± 1.5 db at the two higher frequencies.

In addition to the above measurements, listening tests were made daily by one of the engineers in charge of the equipment, and the girls who conducted the test listened frequently throughout the day by means of monitoring receivers.

Hearing Test Results in Terms of Pressure and Intensity Level

In order to compare the results of the Fair tests with other data on hearing, calibrations have been made of the receivers that were used in the tests. This was done by measuring the pressure levels developed by the receiver at the opening of the ear canal for a small group of people, using a special search tube transmitter so designed that the tube could be inserted under the receiver cap into the opening of the ear canal. Such a calibration gives an ear canal pressure level in terms of receiver voltage levels. The authors are indebted to Mr. W. A. Munson of these Laboratories for the calibrations. They are preliminary in character and may need modification in the light of subsequent studies.

With the aid of these calibrations, ear canal pressure levels may be

[9] F. A. Coles, "Hearing-Test Machines at the World's Fairs," *Bell Laboratories Record*, 18: 290, June 1940.

calculated from the receiver voltage levels measured in the tests. Such calculations for the reference level or condition of zero hearing loss as used in this paper are shown in Table 15. The resulting reference ear canal pressure levels are plotted in Fig. 6. For comparison,

TABLE 15

CALIBRATION OF HEARING TEST EQUIPMENT AT THE REFERENCE LEVEL

	Frequency				
	440	880	1760	3520	7040
Reference voltage level across receivers—db above one volt	−104	−112	−115	−114	−76
705A receiver calibration—db above 0.0002 dyne per sq. cm. per volt	133	134	133	134	98
Reference ear canal pressure level—db above 0.0002 dyne per sq. cm.	29	22	18	20	22

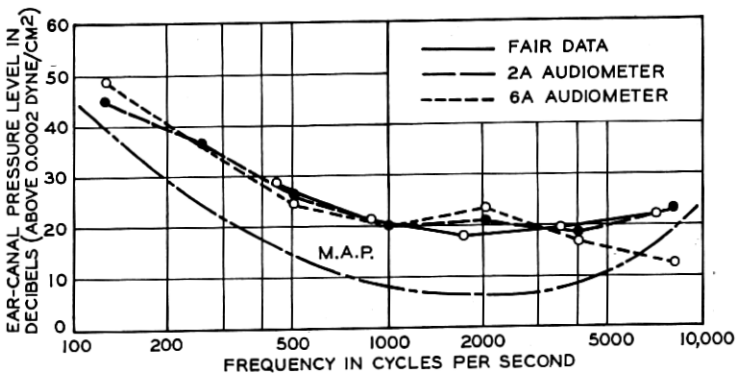

Fig. 6—Ear canal pressure level for certain reference conditions. The measurements for the M. A. P. curve were made nearer the ear drum than those for the other curves. See text.

the ear canal pressure levels corresponding to zero hearing loss on the 2A and 6A audiometers [10] and the minimum audible pressure curve derived by Sivian and White [11] are shown. The audiometer

[10] J. C. Steinberg and M. B. Gardner, "Auditory Significance of Hearing Loss," *Jour. Acous. Soc. Amer.*, **11**: 270 (1940).

In using the Audiometer it is customary to record as the hearing loss the lowest dial setting at which the tone is heard. Threshold would, on the average, be half a dial step lower than the recorded setting. Hence the curves given here for zero hearing loss are 2.5 db lower than those given for zero dial setting in the reference. See also footnote 2.

[11] L. J. Sivian and S. D. White, "Minimum Audible Sound Fields," *Jour. Acous. Soc. Amer.*, **4**: 288–321 (1933).

curves and the Fair curve are based on ear canal pressures measured at the ear opening in the manner just described. The minimum audible pressure curve is based on pressures measured about 1 cm. from the ear drum, which correspond more nearly to ear drum pressure levels. The two types of measurements are undoubtedly quite comparable below 1000 cycles. For frequencies above 5000 cycles and possibly around 2000 cycles it is believed that the pressure at the ear opening is somewhat smaller than the corresponding ear drum pressure.

A comparison of the Fair data with data from two other surveys of hearing is shown in Fig. 7. One curve shows the mean threshold

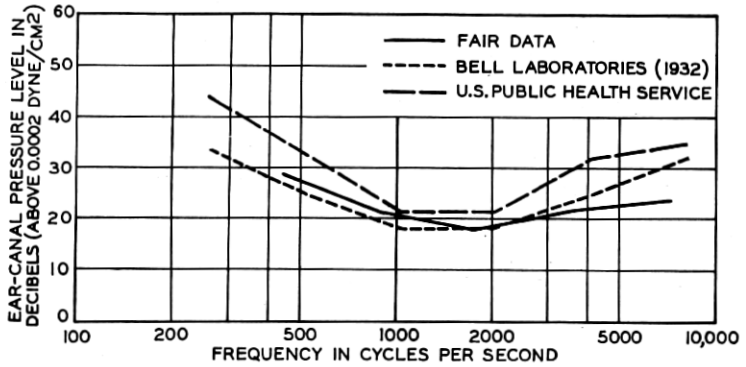

Fig. 7—Comparison of several surveys of hearing, giving mean ear canal pressure level for men aged 20–29.

pressure for men in the 20–29 age group from the Fair data. Another gives values for the same age and sex group in a survey conducted in 1936 by the United States Public Health Service using the 2A Audiometer.[12] This curve is for a somewhat selected group, including only individuals who stated when the test was made that they believed their hearing was normal. The third curve is for members of Bell Telephone Laboratories in the same age and sex group, who were tested in 1931 with a 2A Audiometer.[13] In comparing these results, it should be remembered that differences may be due to three general causes. The groups of people tested may have differed in hearing acuity. The calibrations by which the ear canal pressures were established are subject to error, especially at high frequencies. The conditions of the test, including technique, concentration of subjects, receiver fit, and background noise, were not alike in all cases. Con-

[12] W. C. Beasley, *National Health Survey, Hearing Study Series, Bulletin 5, Table 3*, The United States Public Health Service, Wash. D. C. (1938).

[13] H. C. Montgomery, "Do Our Ears Grow Old," *Bell Laboratories Record*, **10**: 311 (1932). Note that median values were given in this reference, differing slightly from the mean values used here.

sidering all the possible causes of variation the curves seem to be in fairly good agreement.

In order to give a preliminary picture of the prevalence of deafness in terms of free field intensity and frequency, the distribution curves of Fig. 5 were converted into the contour lines shown in Fig. 8. For

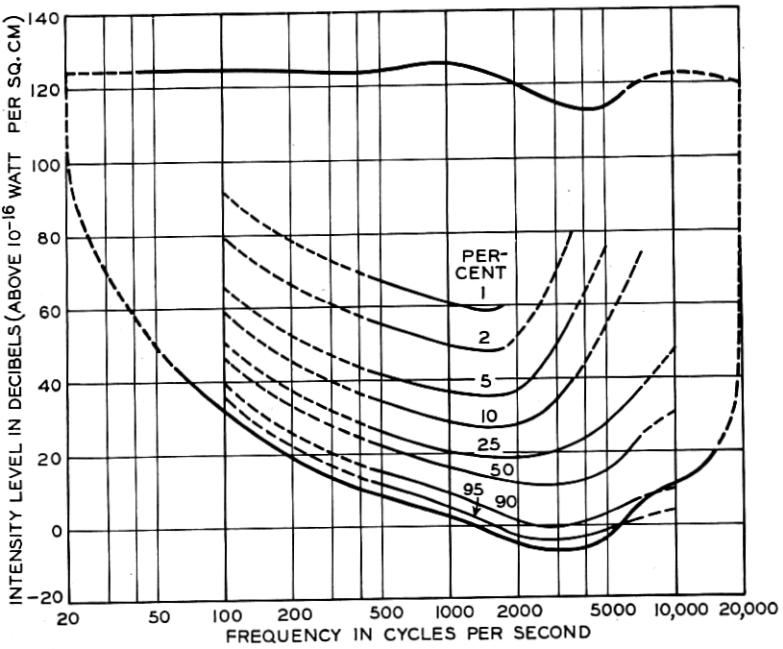

Fig. 8—Contour lines above which lie a given percentage of thresholds for the age group 10–59.

the low frequencies, this conversion was made by applying the differences between the minimum audible pressure and minimum audible field curves of Sivian and White [11] to the ear canal pressure levels of Table 15. For the high frequencies, the conversion was based on a free field calibration of the receivers. The free field intensity levels apply for the condition in which the observer faces the source and listens with both ears. The resulting contours purport to show the percentage of people in the population within the age range 10 to 59 years who cannot hear tones below the given level. The boundary lines forming the auditory sensation area represent the picture of the limits of useful hearing, based upon earlier studies.[14]

The solid portions of the contour lines represent the distributions

[14] H. Fletcher, "Auditory Patterns," *Reviews of Modern Physics*, **12**: 47–65 (1940).

obtained from the results of the Fair tests. The dotted portions represent extrapolations of the distributions beyond the intensity and frequency ranges used in the tests, and are of course speculative in character. The extrapolations to lower frequencies are based on the shape of the contours below 1760 cycles and the high correlation that has been found to exist in individual audiograms for frequencies from 64 to 512 cycles.[15,16] The extrapolations to large hearing losses for the 3520- and 7040-cycle tones were made by extending the curves of Fig. 5 as suggested by comparison with the results of other surveys.

The contours show several interesting things. The range over which hearing acuity varies is quite uniform up to about 2000 cycles, and 90 per cent of the group lie within a range of 30 db. Above 2000 cycles the range increases rapidly. Since most of the sounds met with in daily life have intensity levels greater than the 25 per cent contour, fully three-fourths of the people can hear ordinary sounds throughout the frequency range from 100 to 10,000 cycles.

The Onset of Deafness

With the increasing attention being given to the prevention of deafness by early detection, it is of considerable practical importance to define the beginning, or onset, of deafness. Perfectly normal ears are not exactly alike; some are more acute and others are less acute than the average. How much less acute than average may an ear become before deafness begins? In a preceding section, hearing loss was evaluated on the basis of the handicap that it would impose. In this section we take a different viewpoint and use the term "beginning of deafness" to mean a departure from average hearing acuity sufficient to justify the expectation of associating the departure with a specific cause.

In Fig. 9 there is shown a typical distribution curve for hearing loss. It shows the relative frequency of occurrence of various degrees of hearing acuity among a given class of people. Such curves can be well described for many practical purposes by two quantities, the average hearing loss and the standard deviation. The latter quantity, designated as σ, is a measure of the spread of the individual values from the average.

The experience of statisticians with distributions of observations of widely different character indicates that there is little chance of assigning specific causes for the deviations of observations which lie closer

[15] E. G. Witting and W. Hughson, "Inherent Accuracy of Repeated Clinical Audiograms," *Laryngoscope*, **50**: 259 (1940).

[16] W. C. Beasley, "Correlation Between Hearing Loss Measurements," *Jour. Acous. Soc. Amer.*, **12**: 104–113 (1940).

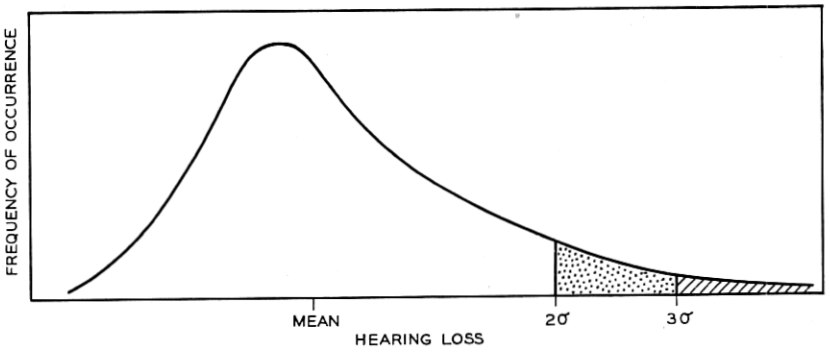

Fig. 9—Typical distribution curve of hearing loss.

than 2σ to the average, because, in this range, many causes are operating and none is predominant. In the range from 2σ to 3σ, the dotted area of Fig. 9, there is a good chance of isolating causes, although the attempt might not be justified if it involved great discomfort, danger or expense. Beyond 3σ, the cross-hatched area of Fig. 9, there is an excellent chance that the cause, or causes, can be isolated.[17] This does not imply that findable causes of hearing impairment do not exist in individuals lying closer to the average than these limits, but merely that the hearing test is not useful in selecting them. The identification of such causes and their treatment are, of course, medical problems.

TABLE 16

HEARING LOSS AT WHICH DEAFNESS BEGINS, IN THE SENSE GIVEN IN THE TEXT

Limit		Frequency			
		440, 880	1760	3520	7040
2σ	Boys	14	15	19	22
	Girls	14	13	11	15
3σ	Boys	21	22	29	34
	Girls	21	20	18	24

This criterion leads to the limits shown in Table 16, beyond which hearing loss is significant in the sense described. Limits are given

[17] It is important to note that the standard deviation to be used in fixing the limits is to be determined after eliminating the effects of impaired hearing. Methods by which this can be done have been developed in connection with statistical methods of manufacturing control. See, for example, W. A. Shewhart, "Economic Control of Quality of Manufactured Product" (Van Nostrand, New York, 1931). The values of σ used in fixing limits in this section are 20 per cent smaller than those given in Table 3.

only for the youngest group because we are primarily concerned with early detection of deafness. Limits for older groups can be obtained in a similar manner.

The table indicates that a smaller hearing loss is significant at low than at high frequencies. At the higher frequencies a smaller loss is significant for girls than for boys. The percentage of the youngest group at the Fairs falling outside of the 2σ limits is given in Table 17.

TABLE 17

PERCENTAGE OF CHILDREN WITH A SIGNIFICANT AMOUNT OF HEARING LOSS

	Frequency			
	440, 880	1760	3520	7040
Boys	4	5	7	8
Girls	5	5	5	6

Use of the 3σ limits would lead to percentages about half as great. It is of interest to note that the 2σ limits are smaller than the amounts of hearing loss which ordinarily constitute a handicap. In other words, a hearing acuity test may have diagnostic significance before the hearing loss is great enough to produce appreciable functional impairment.

Incidence of High-Tone Deafness and of Adenoid Growth

The characteristic difference between men and women in the hearing of high tones seems now to be well established. It has been previously observed by Bunch and Raiford,[7] by Ciocco [18] and more recently by Beasley in a survey of hearing during the health census of 1936.[19] The reason for the difference is not known. It may be occupational in part, although the difference is in evidence in the youngest age group. Recent work reported from Johns Hopkins University,[20] indicates that children with high-tone deafness frequently show pronounced lymphoid tissue growth at the openings of the Eustachian tubes in the throat. In a number of cases, the deafness was cured or held in check by removing the tissue and inhibiting its growth by irradiation with radium during the adolescent period.

If there is a connection between adenoid growth and high-tone deafness, one would expect a greater incidence of adenoid growth in

[18] A. Ciocco, "Observations on the Hearing of 1980 Individuals," *Laryngoscope*, **42**: 837–856, Nov. 1932.

[19] W. C. Beasley, *National Health Survey, Hearing Study Series, Bulletins 5 and 6*, United States Public Health Service, Wash. D. C. (1938).

[20] S. J. Crowe and J. W. Baylor, "Prevention of Deafness," *Jour. Amer. Med. Assn.*, **112**: 585–590, Feb. 1939.

boys than in girls. The results of physical examinations of school children conducted by public health officers and doctors in different parts of the country indicate that such is the case. In all but one of seven surveys,[21] involving more than 18,000 children, the occurrence of adenoid growth was more frequent in boys than in girls. On the average, 6 per cent of boys and girls from 4 to 18 years of age showed pronounced adenoid growth. The ratio of the percentage of girls to the percentage of boys having the defect had an average value of 0.68; for every 100 boys affected there were only 68 girls similarly affected. Analysis of the World's Fair hearing test records shows that 7 per cent of boys and girls from 10 to 19 years of age are deafened for a 7040-cycle tone to the extent of the 2σ limit described in the previous section. The ratio of the percentage of deafened girls to the percentage of deafened boys is 0.75, or 75 girls for every 100 boys. Although it should not be concluded that the similarity of these ratios establishes a correlation between adenoid growth and high-tone deafness, it is believed that they are sufficiently suggestive to justify further study of these defects.

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[21] "The Health of the School Child," *Public Health Bulletin 200, Table 46, page 141,* United States Public Health Service, Wash., D. C. W. Franklin Chappel, "Examination of the Throat and Nose of 2000 Children," *Jour. of Med. Sciences*, **97**: 148–154 (1889). Wm. R. P. Emerson, "Physical Defects in 1000 Children," *Amer. Jour. of Diseases of Children*, **33**: 771–778 (1927).