# A Survey of Room Noise in Telephone Locations *

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This paper describes a survey made to determine the range of magnitudes of room noise present in telephone locations. Measurements were made in a total of 250 locations in New York City and environs, distributed among businesses and residences in accordance with telephone traffic distribution. In each location, measurements were made by a marginal audibility method using the human ear as a part of the measuring device, and by a visual indicating meter. A brief description is included of the apparatus employed with each of these methods. Results are presented for measurements made in various classes of rooms, under winter and summer conditions.

AMONG the projects of the Joint Subcommittee on Development and Research of the National Electric Light Association and Bell System is one (No. 4) which is studying the effects of noise [1] on telephone transmission and methods for its measurement. It was appreciated that, in addition to noises of electrical origin caused by exposures to power circuits or by sources incidental to the operation of the telephone system, there are also noises in the rooms in which telephones are used which have an important effect on telephone service. In studying the effects of noises, it is, of course, necessary to consider both noises of electrical origin and room noises. It was desired that, in laboratory tests of the effects of line noises on speech transmission, typical amounts of room noise should be provided at the test location. The survey described herein was made to obtain room noise data for these laboratory tests.

The methods described should be of general interest in connection with other noise problems. Increasing attention is being given, both in America and in Europe, to the general problem of noise as an undesirable attribute of modern civilization. Some efforts are being made to investigate sources of city noise. Modifications have been made in the design of machines and appliances, such as typewriters, motor cars, electric refrigerators, rotating electrical machinery, and domestic oil burners, so as to reduce the noise involved in their operation. Attention is being given to the quieting of rooms by means of acoustic treat-

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[1] In this joint work, noise is taken to mean any extraneous sound which would tend to interfere with telephone conversation.

Room noise is used to include any extraneous sounds at the place where the measurement is made, except those proceeding from the telephone receiver. It thus includes, in addition to noises such as the rattling of papers or the roar of street traffic, any other sounds extraneous to the telephone conversation, for example, those of other conversations or of music produced nearby.

ment. Studies are being made of the effects of noise on living beings, including effects on the efficiency of workers.[2] In all of this work, quantitative measurement is important.

For the specific problem in hand, it was desired to obtain information on the magnitudes of room noises, as well as some general indication of the frequency composition of typical room noises.

While it is recognized that ordinary room noise is a highly variable quantity changing from instant to instant in intensity and frequency composition, it is felt that sufficient measurements were made to specify the makeup of a typical room noise for use in the laboratory tests, and in addition to obtain an indication of the effect of various factors, described below, upon the noise. Since it was desired to make the measurements as representative as possible of typical telephoning conditions they were made at times of day and in types of locations determined by a study of telephone message traffic. Since the results would be affected by the choice of locations, they are presumably less typical for non-telephone than for telephone purposes.

The residences included in the survey ranged from apartments in large city buildings to small homes in outlying towns. In the business locations were included offices, stores, factories and workshops, and public buildings, such as hotels and clubs.[3] Establishments of various characters were included in each classification; they ranged in size from small stores to great manufacturing plants.

In making all measurements, an attempt was made to simulate the normal conditions which would obtain when a telephone call was placed. If noises existed in the room, which would be discontinued when the telephone was being used, such noises were stopped while the measurements were being made. On the other hand, care was taken to see that none of the normal noises of a particular location was discontinued because of the fact that measurements were being taken.

It was recognized that there would be a difference between the room noise experienced on local and on long-distance calls. The survey was made on the basis of telephone traffic as a whole, which consists predominantly of local calls.

The survey consisted of two series of tests, one made during the months of January, February, March and April, and the other made during the months of July and August. The former series was the more comprehensive, including 205 measurements; the results given herein are based on this series of tests except where specifically noted

[2] D. A. Laird, "The Effects of Noise," *Jl. Acoustical Soc. Amer.*, Jan. 1930, p. 256.

[3] In public buildings, only a very small proportion of the telephone locations tested were in booths or at coin-box telephones.

otherwise. The second series of tests was made for the purpose of determining the difference between the room noise encountered under winter conditions and that encountered under summer conditions. Consequently, a selected group of the locations, which had been measured in the winter, were measured again under summer conditions.

It must be appreciated, in generalizing from the data given, that tests were made in only a limited number of locations.

Two methods were employed in making the measurements described in this paper, one electrical and the other aural. The electrical method employed a condenser-transmitter pick-up, amplifiers, and detector. A weighting network was incorporated in the amplifier to simulate the sensitivity characteristic of the ear. The aural method, known as the "masking method," involved the measurement of the masking effect of the noise on various warbler tones recorded on a phonograph record. Both of these methods will be described in greater detail below.

## General Results

Some of the interesting results which were obtained from this survey may be summarized as follows:

On the average, room noise in residences was about 20 db less in magnitude than that in business locations.

The spread in the magnitudes of business room noises was about 40 db, as compared to 20 db for residence room noises. These spreads include 90 per cent of the measurements, excluding the lowest and highest 5 per cent. The standard deviation of the measurements was about 12 db for business noise and 6 db for residence noise.

Room noises averaged 4 or 5 db higher in summer than in winter.

In general, the magnitude of residence noise was affected to only a minor extent by the size of the town or city in which it was measured.

On the average, the frequency composition of residence noise was about the same as that of business noise. The masking effect of the noise on a tone covering the range 750-1500 cycles was greater than that on ranges above and below this. The magnitudes of components in the lower part of the range covered (about 250-5000 cycles) appeared to be somewhat larger than those in the higher part of this range.

## Methods of Measurement

The two methods which were employed in the survey are as follows:

*Aural Method—Masking of Warbler Tone.*[4]—In this method a tone of varying pitch (warble) is produced and sent into a receiver. The receiver cap is provided with slots shaped so that the observer's ear

[4] R. H. Galt, *Jl. Acoustical Soc. Amer.*, October 1929, p. 147.

canal is always open to the air of the room regardless of how firmly the receiver is pressed against the ear. The tone is generated by means of a phonograph record and a magnetic phonograph record pick-up, and is a variable-frequency tone, the pitch of which varies between certain limits several times per second. An attenuator is placed between the magnetic pick-up and the receiver. The observer sets the attenuator at a point where he can barely recognize the sound of the warble in the presence of the room noise. He also obtains the setting at which he can barely hear the warble in a perfectly quiet room. The difference between these two settings is a measure of the masking effect of the noise in this room upon the warbler tone, for this particular observer.

An idea of the frequency composition of a given room noise may be obtained by using several different warbler tones, each covering a different portion of the voice-frequency range. This is based on the fact that, in general, a tone of a given frequency masks to a greater extent tones that are near it in frequency than tones that are far removed from it in frequency.

The phonograph records used in the present room noise survey were three-band records, i.e., three warbler tones were cut on each record, each tone occupying about one-third of the available space. The frequencies included in the various bands were as follows: high band, 1500–5600 cycles per second; middle band, 750–1500 cycles per second; low band, 250–750 cycles per second. In each band the frequency varied continuously from the lower to the upper limit and back to the lower limit, the period of such a complete "warble" being about one-sixth of a second.

*Electrical Method—Room Noise Meter.*—There is, of course, a number of different electrical methods which might be employed for measuring room noise, ranging from a single over-all measurement to a complete wave shape or frequency analysis. The complete analysis or the measurement of energy present in a considerable number of narrow frequency bands is subject to the disadvantages, for such a survey as this, of slowness of measurement and bulkiness of testing equipment.

The method which was adopted was one based on the use of a frequency weighting simulating the sensitivity of the ear. This frequency characteristic is shown on Fig. 1. It is an equal loudness weighting; that is, the room noise meter was so constructed that different single-frequency noises of equal loudness would give approximately the same meter readings. The shape of an equal-loudness curve is somewhat flatter for high levels of loudness than for low ones. The weighting curve chosen for the meter was for a loudness corresponding to that of a 1000-cycle tone 30 or 40 db above the threshold of audibility. This general level is not far from the middle of the range of levels of room noise components. The loudness data used were those given by Kingsbury,[5] based on experimental data on single-frequency tones.

The sensitivity of the meter is such that a 1000-cycle tone about 28 db above threshold would give a reading of 0 db on the meter scale.

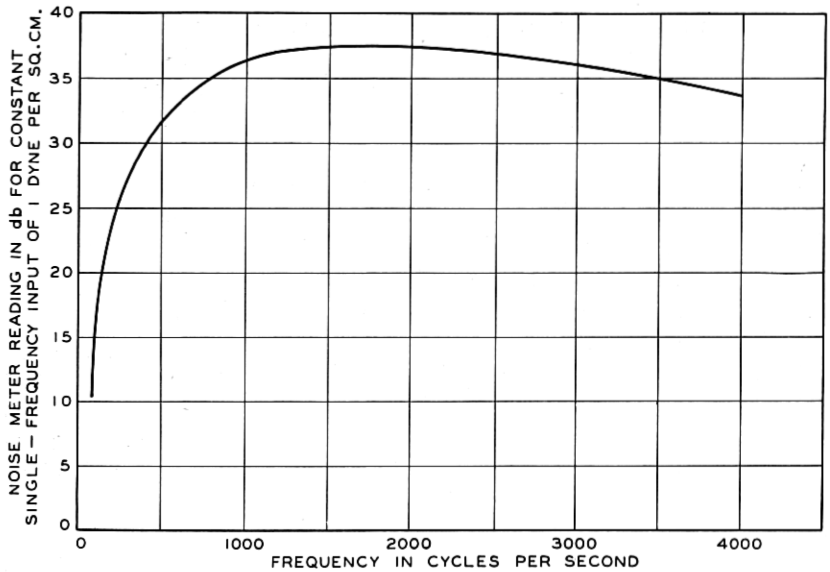


Fig. 1—Response characteristic of room noise meter.

The room noise meter employed is shown together with its auxiliary equipment in Fig. 3. It consists of a condenser transmitter for converting acoustical energy into electrical energy, six stages of amplification for raising the level of the noise currents sufficiently to operate a thermocouple meter indicating device, and a weighting network, as de-

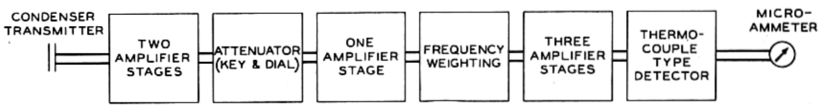


Fig. 2—Schematic diagram of room noise meter.

scribed above, as well as certain apparatus not employed in obtaining the results reported here. The general layout of the circuit is indicated in the schematic diagram of Fig. 2. A portable battery supply and means for calibrating form the necessary auxiliary equipment. An

[5] *Physical Review*, Vol. 19, April 1927, pp. 588–600.

adjustable attenuator controlled by a key and a dial is provided between stages of the amplifier so that the noise energy being measured may be brought within the range of the meter over a range of levels of 80 db (corresponding to a power range of 100,000,000 to 1).

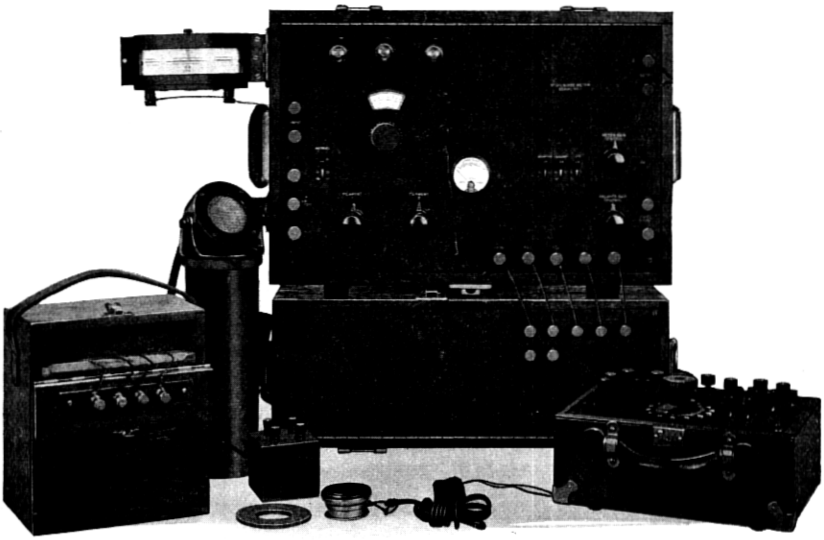

Fig. 3—Room noise meter and auxiliary equipment.

*Operation of the Room Noise Meter.*—The noise meter is first calibrated, as described below, so that its sensitivity is set at a predetermined value. The condenser transmitter is then placed at the spot where it is desired to measure noise, and the gain of the amplifier is adjusted by means of a key and dial until the needle of the microammeter in the output circuit fluctuates about a given point. The settings of the key and dial then give a measure of the noise. In addition to the average readings obtained in this manner, readings of the fluctuations in the noise can be similarly obtained. As an aid in the reading, the microammeter scale is calibrated in decibels.

The calibration of the meter in the field consists of a check on the over-all sensitivity of the instrument. The filament currents and plate voltages are adjusted to the correct values. Then a fixed percentage of the electrical output of a standard buzzer, the current from which is measured by a thermocouple, is fed into a special receiver which is placed in a prescribed way on the condenser transmitter. The gain of the amplifier is then adjusted until the output microammeter needle reaches a predetermined point. The sensitivity of the meter will then be as shown on Fig. 1.

An over-all calibration of the meter, as a function of frequency, is given on this figure. To obtain this, separate determinations were made of the volts generated by the condenser transmitter per unit of pressure, and the meter reading per volt generated by the transmitter, as a function of frequency; and the results were combined to give the values shown. Harmonics in the testing waves were reduced to such a point that they did not affect the results. After a substantial part of the survey had been completed, a check was made of the electrical portion of the calibration, and the changes found were quite negligible.

*Accuracy of the Meter.*—The precision of the apparatus is substantially greater than the precision with which ordinary varying noises can be measured. The readings obtained for steady inputs are proportional to the input, with an error of less than 1/2 db, over the entire range of noise amplitudes found in the survey. The apparatus is shielded electrically. In only one case did electrical fields produce any observed errors in the readings; this was when an attempt was made to measure the room noise near a rotary converter in a power station. The vacuum tubes are mounted in such a way that the effects of ordinary mechanical vibration on the readings are negligible.

*Comparison of the Two Methods.*—In general, the meter method gives results in physical terms while the masking method gives them in terms of effects on the ear; consequently, the choice of the method to be employed in any particular case depends somewhat on the use to which data will be put. It is true that the meter includes a network to simulate the sensitivity of the ear for various frequencies; it does not, however, simulate other properties of the ear, such as the departures from linearity in response by which subjective tones are produced by the ear mechanism, and the complicated way in which one sound masks another.[6]

The meter method, unlike the masking method, avoids any errors due to variations in human ears. This advantage is offset to some extent by the fluctuations of the meter needle, which make it difficult to obtain the mean reading if the noise is unsteady as is the case with most room noises.

In the case of noises of a distinctly intermittent, staccato character, the warbler tone can be heard and recognized in the brief intervals when the noise is a minimum. A preliminary investigation showed that, for a noise of this sort, the relation between readings obtained by the masking method and by the meter method was different from the relation obtained for a steady noise, the warbler readings being relatively lower in the case of intermittent noise.

[6] R. L. Wegel and C. E. Lane, "Auditory Masking and Dynamics of the Inner Ear," *Physical Rev.*, Feb. 1924.

Both methods were used in the survey, because it was felt that each gave information which could not be as accurately obtained from the other, and also because the use of two methods enabled each one to be used as a check upon apparatus defects which might occur in the other.

In using the masking method, data were taken by two experienced observers and corresponding measurements averaged. All meter measurements were made by one observer.

## Results of Survey

*Noise in Business Locations.*—One hundred and nine business locations were visited. The magnitudes of the noises measured varied from that found in a doctor's quiet office to the din of a large manufacturing plant. Distribution curves for the noises measured are shown in Fig. 4 for the meter method and Fig. 5 for the masking method. For any point on one of these curves the corresponding per cent of all of the measurements made had values equal to or greater than the indicated abscissa value.

It may be seen that with the exception of the "high" curve of Fig. 5 the curves for meter and masking methods are fairly similar in shape. The "middle" curve has been selected to represent the masking method.

If there are excluded as extremes those noises which were so low that 95 per cent of all the noises measured equaled or exceeded them, and those which were so high that only 5 per cent of the measurements equaled or exceeded them, the spread of noise magnitudes is seen to be about 40 db. The standard deviation of the measurements is about 12 db.

As shown on Figs. 4 and 5 the median business room noise would produce a reading of 23 db on the meter scale and a masking of 27 db on the high-frequency warbler tone, 39 db on the middle-frequency tone, and 31 db on the low-frequency tone. The average business room noise was about 2 db higher than the median.

Some conception of the amounts of noise represented by these figures may perhaps be gained from the following. The extremely loud noise measured in a local station of the New York subway while an express train was passing produced a meter reading of 70 db, while the lowest noises measured in the survey, in quiet residences, gave readings near 0 db.

Data on noise at the business locations tested have been grouped so as to show the average differences in the room noise values obtained for different types of business and for different sizes of towns. It will be appreciated that only a very small number of measurements were in-

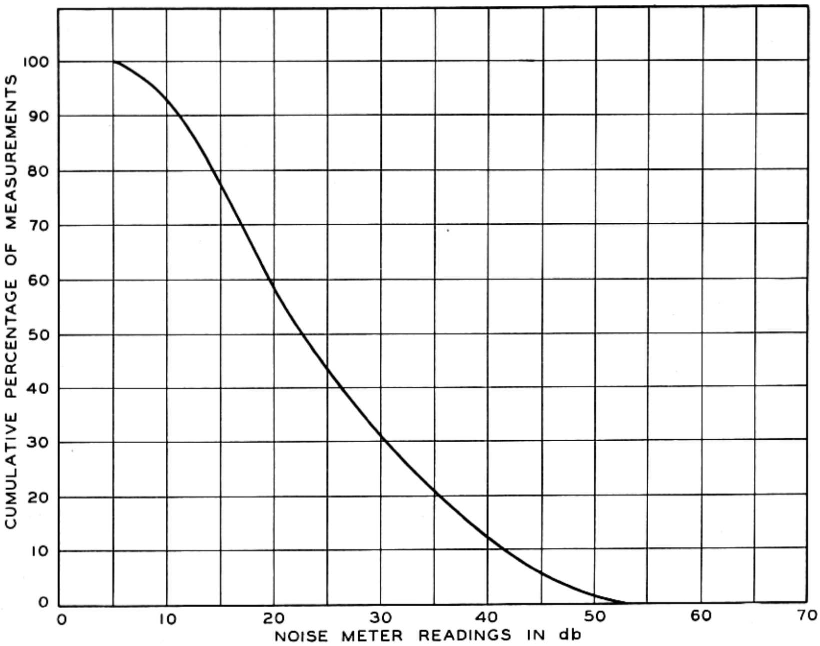


Fig. 4—Results of noise meter measurements of noise in business locations.

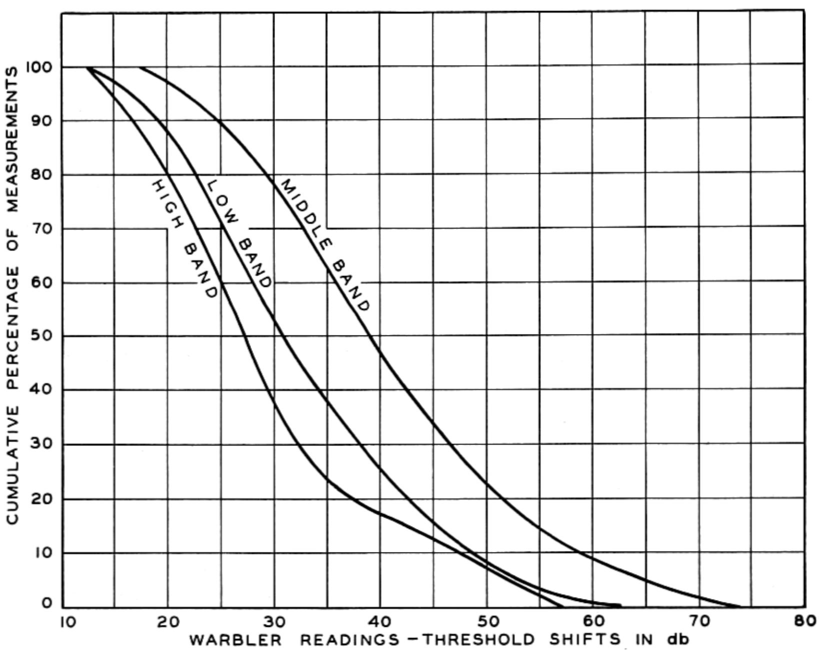


Fig. 5—Results of measurements of noise in business locations by masking method.

cluded in each sub-classification, and that consequently it is not safe to generalize from these sub-groupings as to room noise conditions in general.

Averages of the room noise measurements for the different types of business locations are shown in the following table.[7]

| Type of business location | Masking of middle-frequency tone | Meter reading | Number of measurements |
|---|---|---|---|
| Offices | 42 db | 24 db | 34 |
| Stores | 34 | 18 | 34 |
| Factories | 57 | 40 | 18 |
| Public buildings | 35 | 21 | 23 |
| Average of all businesses (weighted according to number of measurements made) | 40 | 25 | 109 |

The above figures show a significant difference between the noise measured in factories and that measured in other types of location. The other differences shown were found not to be significant when examined in the light of the spread in values for individual locations in each class.

Averages of the business room noise measurements obtained in various sizes of towns are shown in the table below.

| Size of town | Masking of middle-frequency tone | Meter reading | Number of measurements |
|---|---|---|---|
| Class A (over 400,000 pop.) | 45 db | 26 db | 39 |
| Class B (100,000 to 400,000 pop.) | 37 " | 22 " | 18 |
| Class C (10,000 to 100,000 pop.) | 42 " | 27 " | 41 |
| Class D (less than 10,000 pop.) | 27 " | 11 " | 11 |

These figures indicate that (with the exception of Class C towns) the business noise measured in large cities was greater than that in smaller towns. This is believed to hold true despite a fairly large spread in individual measurements within a given class. The exception in the case of Class C towns is explained by the fact that a fairly large percentage of the measurements in this class were made in large factories.

Room noise in business locations was observed to be quite complex in

[7] It will be noted that in the results given, the difference between the masking of the middle-frequency tone and the meter reading is relatively constant. It was found that for any considerable sub-group of the measurements, this difference was not far from 15 db. This figure, of course, would not in general hold for a single noise selected at random. There was a general tendency for the difference to be somewhat larger for larger values of noise.

frequency composition. The masking effect of the noise on the middle band was greater than that on the high and low bands. In order to give an approximate interpretation of this in terms of pressures in various frequency regions, account must be taken of the relative magnitudes of threshold pressures in the three warbler frequency bands, since the masking effects were obtained by subtracting threshold settings of the attenuator from the settings made in the presence of the noise. For

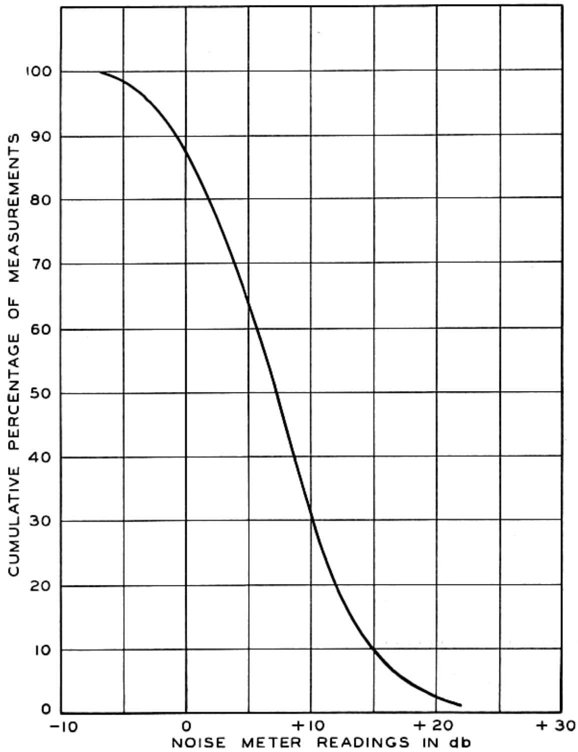


Fig. 6—Results of noise meter measurements of noise in residence locations.

the middle and upper bands, threshold pressures are about the same; hence, the lower values of masking for the high range indicate that components in this range are in general relatively weak. As previously determined,[8] threshold pressures at frequencies in the low band are several decibels higher than those in the other bands. Combining the values of masking for the low and middle bands with the corresponding threshold pressures, it is seen that the physical magnitudes of compo-

[8] H. Fletcher, "Useful Numerical Constants of Speech and Hearing," *Bell System Tech. Jl.*, July 1925.

nents in the low- and middle-frequency ranges are in general not far different. The above analysis is, of course, very rough, as the whole range from 250 to 5600 cycles is divided into only three bands.

*Room Noise in Residence Locations.*—Measurements were made in 96 residence locations.

Figs. 6 and 7 show distribution curves for these measurements. Compared with the corresponding measurements made in business

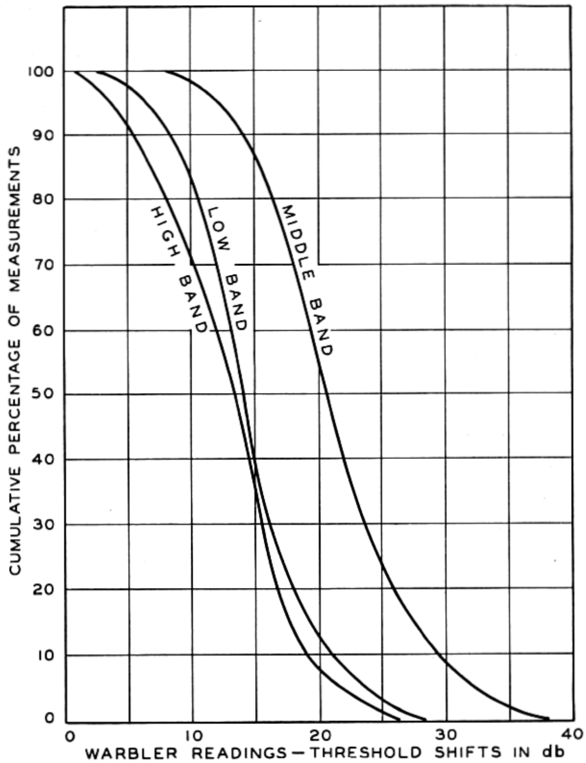


Fig. 7—Results of measurements of noise in residence locations by masking method.

locations it is apparent that the room noises encountered in residences were not only much smaller in magnitude but also varied less in magnitude than business room noises. The average of the residence room noises is about 18 db less than the average of the business room noises, while the spread in residence room noise (using the 95 per cent and 5 per cent points on the curves as limits) is 20 db, compared to 40 db for business noise; the standard deviation of the residence measurements is 6 db, compared to 12 db for the business neasurements. Unlike the curves for business noise, the curves for residence noise are very symmetrical, showing similar distributions above and below the average values.

As shown on Figs. 6 and 7, the median residence room noise would produce a reading of 7 db on the meter, and a masking of 12 db on the high-frequency warbler tone, 20 db on the middle-frequency tone, and 13 db on the low-frequency tone. The average was about the same as the median.

The average of the room noises measured in single-family houses was practically the same as the average of the noises measured in apartments.

Averages of the residence room noise measurements obtained in towns of various sizes are shown in the following table:

| Size of town | Masking of middle-frequency tone | Meter reading | Number of measurements |
|---|---|---|---|
| Class A (over 400,000 pop.) | 20 db | 7 db | 33 |
| Class B (100,000 to 400,000 pop.) | 20 " | 8 " | 14 |
| Class C (10,000 to 100,000 pop.) | 23 " | 6 " | 37 |
| Class D (less than 10,000 pop.) | 17 " | 7 " | 12 |

It will be observed from this table that the residence noises measured in large cities were no greater than those measured in smaller towns. A study of the data showed that 27 of the 33 measurements made in Class A towns were made in residences which would be classed as apartment houses. It is possible that the noise usually associated with big cities is confined chiefly to non-residential locations, and that apartments on side streets are no noisier than residences in smaller towns. It should be recalled, however, that the number of measurements in each class of town was very small. In any case the data tend to show that the difference between residence noise in the large city and that in the smaller town probably is not extremely large. The measurements for Class A cities were made chiefly in Manhattan and Brooklyn with a small number in Newark.

It was found, in a manner similar to that discussed above for business noise, that the average residence room noise was quite complex in frequency makeup, and apparently did not differ materially from the average business noise in the relative amplitudes of low and high frequencies.

*Comparison of Room Noise in Winter and Summer.*—Forty locations were visited both in summer and in winter and the data compared. It was found that both business and residence noises were somewhat greater in summer than in winter, the average difference being 4 or 5 db. The spread in values obtained under summer conditions was less than that found for the winter conditions. This was because the noises which showed the least magnitude, when measured in winter, were found to be higher under summer conditions, while the highest noises measured failed to show an appreciable change with season. These highest noises were largely caused by indoor machinery, and would not be appreciably modified by outside sources.

The average frequency composition of the noises measured under both summer and winter conditions seemed to remain about the same as far as could be determined.

## Selection of Typical Room Noise and Its Reproduction

The data obtained have been used in determining the characteristics of a typical room noise to be recorded on a phonograph record and reproduced for use in laboratory tests.

Since the data revealed no difference between the average frequency composition of great and small noises, it has been possible to choose a single recorded noise and to vary merely the amplitude of the reproduced noise, keeping its frequency makeup constant.

The recording and reproduction of such a noise have presented problems, particularly from the point of view of naturalness. It has been found difficult to reproduce a noise by simple means in such a way as to give the illusion that the noise is real, not artificial. The requirements for reproducing a noise which will be typical in its effect on the intelligibility of speech transmitted over telephone circuit are, however, considerably less severe than those for obtaining naturalness. Three main factors seem to be involved in the problem. In the first place, room noises often contain high-frequency components, undoubtedly including some extremely high frequencies. These components, while they are generally of low energy content, seem to contribute substantially to the naturalness of the sounds. The effect of these components on the intelligibility of speech transmitted over a telephone circuit would, however, be much less than their contribution to the naturalness of the noise, since the transmitted speech is generally limited to a band of not more than 3000 cycles. The frequency band transmitted by the recording and reproducing system was nearly twice this amount, being limited both by the mechanical characteristics of the apparatus and by the unavoidable noise generated in this apparatus, the amount of this noise increasing as the band width increases. Second, room noises emanate from a considerable number of sources located in different positions, so that in order to reproduce them with complete fidelity

LIST OF TOWNS WHERE ROOM NOISE SURVEY MEASUREMENTS WERE MADE

| Size of town | Name of town | Number of measurements | | | |
|---|---|---|---|---|---|
| | | Business | | Residential | |
| Class A (over 400,000 pop.) | Brooklyn, N. Y. | 7 | | 18 | |
| | Manhattan, N. Y. | 32 | | 13 | |
| | Newark, N. J. | 0 | | 2 | |
| | Total | | 39 | | 33 |
| Class B (100,000 to 400,000 pop.) | Jamaica, N. Y. | 11 | | 11 | |
| | Yonkers, N. Y. | 7 | | 3 | |
| | Total | | 18 | | 14 |
| Class C (10,000 to 100,000 pop.) | Bloomfield, N. J. | 0 | | 2 | |
| | East Orange, N. J. | 7 | | 9 | |
| | Flushing, N. Y. | 0 | | 5 | |
| | Harrison, N. J. | 3 | | 0 | |
| | Kearny, N. J. | 6 | | 0 | |
| | Maplewood, N. J. | 6 | | 10 | |
| | Milburn, N. J. | 4 | | 1 | |
| | Mt. Vernon, N. Y. | 6 | | 4 | |
| | New Rochelle, N. Y. | 0 | | 2 | |
| | Orange, N. J. | 4 | | 0 | |
| | Summit, N. J. | 2 | | 2 | |
| | West Orange N. J. | 3 | | 2 | |
| | Total | | 41 | | 37 |
| Class D (less than 100,000 pop.) | Hollis, N. Y. | 6 | | 7 | |
| | Madison, N. J. | 0 | | 3 | |
| | Pelham, N. Y. | 3 | | 1 | |
| | Richmond Hill, N. Y. | 2 | | 1 | |
| | Total | | 11 | | 12 |
| | Grand total | | 109 | | 96 |

each source must be reproduced separately in its own position. On account of binaural effects in hearing, the proper locating of sources seems to have a considerable effect on naturalness. The most practical method of securing an approximation to this effect in the reproduced noise is to dispose a number of loudspeakers in different places in the room, chosen by test so that false directional effects are avoided. Third, the effects of reverberation must be considered. A noise picked up in a highly reverberant room, and reproduced in another highly reverberant room, would have in it two sets of reverberations. The best method of taking care of this seems to be to make artificial adjustments in the reverberation in the two rooms. Finally, there is a residual effect due to the fact that a person experiencing an actual noise is aided in his recognition of the noise by visual and other factors enabling him to refer it easily to its source; these are, of course, not present when the sound is reproduced.

## Conclusions and Acknowledgment

While a certain amount of work on room noise conditions in telephone locations had been previously carried out, this survey represents a considerable advance in knowledge of room noise magnitudes. It provides data for work on the effects of noise on telephone transmission as well as furnishing certain information of wider interest. The methods of measurement employed, when further developed in the light of the experience gained in this work, should prove valuable in other room noise investigations.

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