The Computation of the Composite Noise Resulting from Random Variable Sources

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A statistical method is described for computing the meter reading which would be obtained on a sound level meter when used to measure room noise resulting from the random concurrent operation of a number of intermittent or continuous noise sources. The application of the method in the solution of practical problems is illustrated.

IT is generally recognized that the effects of noise upon the individual exposed to it are, to a large extent, dependent on the loudness of the noise. Various tests have been made of the relation between loudness and the different effects of noise, such as interference with hearing, reaction on the nervous system, disturbance of rest, reduction of working efficiency,[1] etc.

It has also been recognized that the ear itself, in general, is not a convenient means for the accurate measurement of loudness, especially in absolute terms. To overcome this difficulty sound level meters [2] have been made available for the measurement of acoustic noises or sound in general.

This paper is concerned with the application of such sound level meters in the study of noise problems and, in particular, with the question of determining the contribution of individual noise sources to the general "composite noise" including noise sources whose outputs are random, discontinuous variables. The paper does not concern itself with the attributes of loudness or the effects of noise, but merely with the computation of a meter reading of the total noise from available measurements of the noise components. It is recognized, of course, that not only are sound level meter readings an incomplete description of the effect of a change in noise but that considerable experience is required to appreciate properly the significance of the decibel unit employed.

Types of Problem

The method described in this paper has been developed to meet a very practical need experienced in the solution of a large variety of noise problems. To illustrate, consideration may be given to reducing

[1] For reference see Bibliography.

the noise in a room by excluding street noise, using quieter office equipment or sound absorbing material. Each of these measures will involve a certain expense and will reduce room noise a certain amount. Which of these measures will be of greatest benefit and most economical, i.e., give the greatest noise reduction per dollar expenditure?

In another assumed case, the noise from a certain noise producer, a piece of machinery, a ventilating system, etc., is known. Will this apparatus be objectionable in the particular location for which it is considered?

These and similar questions can be answered by computation while the project is still in the planning stage, whereas measurements can be made only after the change has been made, i.e., after the money for the project has been spent.

The computation method, as these illustrations show, is useful in specifying apparatus and in planning working or living quarters from the noise standpoint, in studying the comparative effectiveness of various noise reducing means, etc. The method has been used in many practical problems in this way, with satisfactory results. In a number of applications covering noise from 55 to 75 db sound level the computed and measured absolute values agreed, on the average within 1.0 db, and in the worst case within 2.0 db. Computations of the effect resulting from modifications of the noise sources were checked within closer limits. A few illustrations of applications are given at the end of this paper.

The Impulsive Character of Noises

Acoustical noise frequently is composed of sounds from a large number of sources each of which produces a relatively small proportion of the total noise. Usually these individual noise sources are discontinuous, consisting of a series of individual impulses. Consider, for instance, noise from a busy street. The hearers' first impression is that of a general roar. After a period of listening, however, a variety of individual sources may be distinguished, such as: The movement of automobiles, squeaking of brakes, whistles, street car wheels and bells, hammering and riveting from building operations, footsteps and conversations of people, etc. Each of these sources has a distinct time pattern and even those that appear most steady can frequently be broken up into impulses. For instance, the noise from an automobile passing down the street is composed of a series of impact noises which depend on unevenness of the pavement, the driving gears, number of cylinders in the engine, etc.; the hum of conversation of people in the street is composed of individual syllabic speech sounds from the different talkers.

These impulses occur at a rate which usually is not uniform. Provided, however, that the general conditions do not change, the rate approaches uniformity if the time interval considered is sufficiently large. Some of the impulses from the different sources are superimposed upon each other while others fall in the intervals between the impulses from other sources. As the amount of noise increases, two general phenomena are observed: First, the loudness of the noise increases due to the superposition of impulses; secondly, the noise becomes steadier due to the more complete filling in of relatively silent intervals (20 db or more below the average).

Definition of Terms

The solution of the problem of computing the total noise from its component parts requires the definition of a number of terms and a study of the characteristics of the implied measuring instrument.

Definition 1

Each individual producer of noise is referred to as a "noise source."

Illustrations of noise sources are: For the case of room noise—the conversation of one person, the noise from a typewriter or from a fan in the room. A number of sources of street noise have been mentioned above in illustrating the impulsive character of common noises.

Definition 2

The deflections on the measuring device (sound level meter) produced by the impulses of a single source are called "source peaks."

A peak is obtained by passing a noise impulse into a sound level meter. Depending on this measuring device, the characteristics of a peak differ from those of an impulse. The characteristics of the sound level meter, therefore, are important in connection with this computation method. Three of these, the frequency response, the rule of combination of the frequency components of a complex wave, and the dynamic characteristic of the indicating meter, are here considered in detail. These are defined in the "American Tentative Standards for Sound Level Meters" approved by the American Standards Association [2] from which the following abstracts are made:

1. The free field frequency response of a sound level meter, provided only one response is available, shall be the 40 decibel equal loudness contour modified by differences between random and normal free field thresholds. Methods are given in the ASA specification for correcting the reading when the microphone of the sound level meter responds differently to sound waves arriving with different angles of incidence.

2. The rule of combination is specified so that the power indicated for a complex wave shall be the sum of the powers which would be indicated for each of the single frequency components of the complex wave acting alone.
3. The dynamic characteristic of the indicating instrument is to be such that the deflection of the indicating instrument for a constant 1000-cycle sinusoidal input shall be equalled by the maximum deflection of the indicating instrument for a pulse of 1000-cycle power which has the same magnitude as the constant input and a time of duration lying between 0.2 and 0.25 second.

In addition, the method of reading the sound level meter is important. Where the noise is steady, it is fairly obvious how the meter should be read. When, however, the noise fluctuates, a certain amount of judgment is involved in obtaining an average. A satisfactory procedure in this event is to take a series of instantaneous readings of the noise peaks at approximately 5-second intervals for a period of time sufficient to include all noise sources. One or more of these series of measurements may be made depending on the regularity of occurrence of the noises of interest. The average and standard deviation of the fluctuating noise may then be determined from these measurements.

Using simplifying approximations based on these specified characteristics a peak may be defined as follows:

A peak is an impulse integrated by the measuring device. Its frequency components are weighted in accordance with the loudness weighting incorporated in the meter and combined by direct power addition.

It will be seen from the foregoing that the duration of the source peaks depends on the period of the indicating meter. It has been found that 0.2 second gives satisfactory correlation between computed values and actual sound level meter readings, and is in reasonable agreement with the above specified characteristics. Due to the meter characteristics, full magnitude is not indicated for impulses shorter than 0.2 second. Several impulses in the same integration period appear as a single peak on the meter. Impulses lasting longer may be regarded as producing a number of consecutive peaks. A steady noise, for instance, would be considered as consisting of a series of consecutive peaks of equal magnitude.

On the assumption of discrete integration intervals the average reading on a single source is the arithmetic mean of the intensities of the source peaks. Hence for a source, j, producing on the average m_j peaks per minute of intensities, I_{1_j}, I_{2_j}, I_{m_j}, the average reading on the meter is given by

$$I_j = \left(\frac{1}{m} \sum_{i=1}^{m} I_i \right)_j. \quad (1)$$

On the assumption of discrete integration intervals, furthermore, a source can produce no more than one peak every 0.2 second. The maximum number of peaks per minute that can be obtained from a single source, consequently, is 300.

Definition 3

The noise from all sources as measured by the indicating meter is called composite noise.

Room noise measured at a given observing position in the room is an illustration of composite noise. The peaks of a composite noise are called "composite peaks." Composite peaks have similar characteristics to source peaks as regards duration, frequency weighting, etc.

Statistical Method of Combining Noise Sources

In developing this computation method the principal aim of the authors has been to provide a practical, working method which is easy to handle yet is sufficiently reliable for engineering purposes. In accordance with this objective, a number of simplifying assumptions have been made. Some of these have been indicated in connection with the discussion of the assumed characteristics of noise peaks. The division of the time into discrete 0.2 second intervals is another approximation which has been made. The statistical treatment, in addition, includes approximations which are usual in probability mathematics of this type. Practical experience has shown that these approximations do not lead to errors which affect the usefulness of the method.

In the following an expression is derived for computing the average intensity of the composite noise from the average intensities of the source peaks and their number. Consideration is first given to the case when only a single source peak may occur in each 0.2 second interval. The consideration is then extended to cover the general case when more than one source peak may occur in a 0.2 second interval.

When only one source peak may occur in a 0.2 second interval, the average intensity $\bar{I}$ of the composite noise for these intervals is the arithmetic mean of the intensities of the source peaks, weighted by their frequency of occurrence.

$$\bar{I} = \frac{m_1}{N} I_1 + \frac{m_2}{N} I_2 + \cdots \frac{m_n}{N} I_n, \quad (2)$$

where

$I_1, I_2, \cdots I_n$ = average intensities of the sources 1, 2, $\cdots n$,
$m_1, m_2, \cdots m_n$ = number of peaks of each source per minute,

$N = \sum_{j=1}^{n} m_j$ = total number of source peaks per minute.

If several source peaks occur in the same 0.2 second interval, they will appear as a single composite peak on the meter. On the assumption of discrete 0.2 second intervals, these source peaks coincide. Their intensities, consequently, add up directly. For instance, if two source peaks occur during each integration period, the average intensity of the composite noise will be twice the arithmetic mean of the intensities. Similarly, the average intensity of the composite noise, when the number of source peaks per 0.2 second interval averages α, will be

$$I = \bar{I} = \alpha\left(\frac{m_1}{N} I_1 + \frac{m_2}{N} I_2 + \cdots \frac{m_n}{N} I_n\right). \tag{3}$$

Let M = the total number of composite noise peaks per minute. The maximum value that M can have is 300, the number of integration periods per minute. Unless the composite noise is continuous, however, there will be a certain proportion of time, t_0, in which no composite peaks occur. M then can be determined from the relation:

$$M = (1 - t_0)\, 300. \tag{4}$$

If, on the average, α source peaks per 0.2 second occur, the following relation holds between the total number of source peaks, N, and the number of composite peaks:

$$M = \frac{N}{\alpha}. \tag{4a}$$

Introducing this expression in equation (3) gives

$$I = \frac{m_1}{M} I_1 + \frac{m_2}{M} I_2 + \cdots \frac{m_n}{M} I_n. \tag{5}$$

As shown by equation (4), M is a function of t_0, the proportion of time in which no composite noise peaks occur. The value for t_0 can be found, as follows: The proportion of time when source j has a peak is equal to the probability $p_j = m_j/300$, and the proportion of time when source j has no peak is $q_j = 1 - p_j = 1 - (m_j/300)$. The proportion of time, t_0, when there are no peaks from any source then is equal to the product

$$t_0 = q_1 q_2 \cdots q_j \cdots q_n.$$

This expression can be simplified, when the number of sources is large and none is particularly outstanding, by considering, instead of the individual sources, an average source having $m = N/n$ peaks.

The average probability then is

$$p = \frac{m}{300} = \frac{N}{300n},$$

and

$$q = 1 - \frac{N}{300n},$$

which leads to the approximation:

$$t_0 = q^n = \left(1 - \frac{N}{300n}\right)^n.$$

This expression can be further simplified when the number of sources is large and $p = N/300n$ is small by using the Poisson exponential limit:

$$t_0 = \left(1 - \frac{N}{300n}\right)^n \cong e^{-N/300},$$

where

$$e = 2.718 \cdots.$$

so that for this case

$$M = (1 - e^{-N/300})300. \tag{4b}$$

Measurement of Source Distributions

The method outlined in this paper for computing the composite noise assumes that information on the noise sources is available. Such data, therefore, must be obtained before the method can be applied. Representative measurements for a particular type of noise source, however, when once obtained, can be used in any future noise computation involving such a source.

It is necessary to consider carefully the acoustic conditions under which the sources are measured. For greatest accuracy the ambient noise level at the point of measurement should be 20 db or more below the average level of the source. Errors due to reflections can be minimized by making the measurements at a relatively short distance from the source out of doors or in a room that contains a large amount of absorbing material. A distance of 2 feet is a convenient value for most cases, and will be used as a reference value throughout the rest of this paper.

Readings should be obtained on all the noise peaks while the source is being operated in a normal manner. If the scale of the particular sound level meter used is limited, it may not be possible to read the highest as well as the lowest peaks with a single potentiometer setting. In such cases, the distribution of peaks may be measured in two or more groups.

Figure 1, Curve *A*, illustrates the measurement of source peaks in the laboratory and represents a cumulative distribution of the peaks from a typewriter as measured at a horizontal distance of about 2 feet from the type bar guide. The machine was operated by an experienced typist at an average rate.

When it is not possible to simulate actual conditions of use of a device sufficiently well in the laboratory, measurements on the source

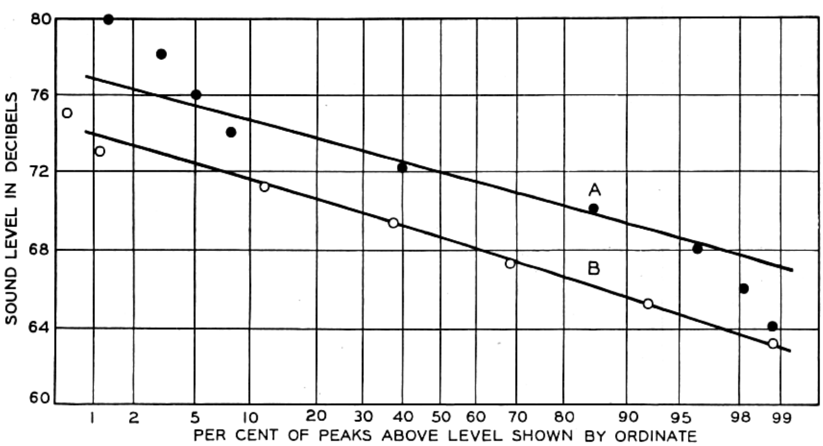

Fig. 1—Distribution of noise peaks in a typing room.

will have to be taken in the field. This may involve measuring in the presence of considerable noise from other sources. In general, it is feasible only to measure source peaks which are above the ambient noise level. If, however, an appreciable number of peaks is above this noise level, the rest of the distribution can be estimated and the average value determined. Statistical methods for doing this have been worked out for the case of normal distribution curves.[3] Experience has indicated that the distributions of noise in db frequently are approximately normal, so that these methods are applicable.

Figure 2 is an illustration of a distribution of a group of sources measured under adverse noise conditions. This curve shows the noise which came from the metal trays in a cafeteria. The distribution had to be obtained in the field because it was not feasible to estimate in the laboratory how the customers would handle the trays. The points on the curve indicate the peaks that could be measured in the cafeteria which had an average composite noise of 66.5 db. It will be seen that the lowest peaks that could be measured satisfactorily were at 74 db sound level. The rest of the curve was estimated using the statistical methods referred to above.

The curves in Figs. 1 and 2 are plotted on "arithmetic probability paper." On this paper, cumulative normal distributions appear as straight lines.

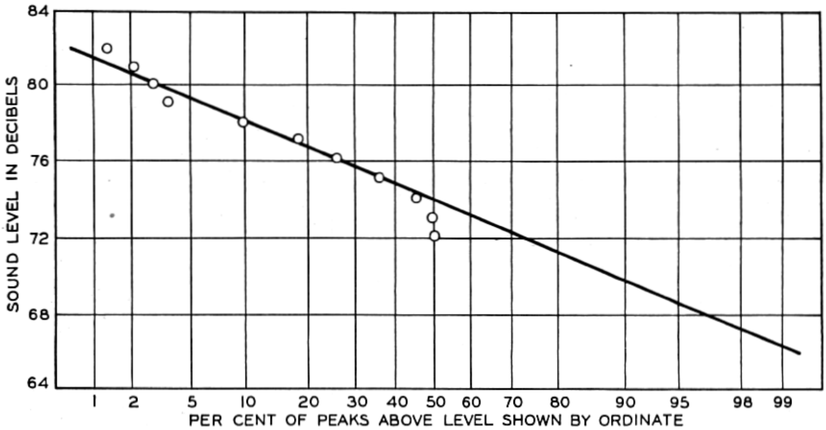

Fig. 2—Distribution of noise peaks from metal trays in a cafeteria.

Effect of Room Characteristics

Generally the noise sources are at various locations so that it is necessary to determine how much the noise from each is reduced by its distance from the observing point assumed for the computation.

Since it is not the primary concern of this paper to discuss the distribution and decay of sounds in rooms, only a very simple approximate method of computing distance losses, based on the classical theory of the steady-state distribution of sound in a room, is given here. This method has been found adequate for practical purposes in rooms having relatively simple geometric shape and large enough dimensions so that the sound is diffused. For a more complete treatment of room acoustics the reader should refer to the literature on this subject.[4]

The total steady-state intensity, I_T, at an assumed observing position in a room consists of two parts: I_R, the reflected sound intensity and I_D, the direct sound intensity, so that:

$$I_T = I_R + I_D.$$

Assuming the reflected sound to be uniformly distributed in the room, it can be shown that:[4]

$$I_R = \frac{.0038E}{\dfrac{aS}{S-a}},$$

where E = power emitted by source, in ergs per second,
S = total surface area of the room in square feet,
a = absorption in square feet of equivalent open window.

Introducing $F = aS/(S - a)$, the above becomes:

$$I_R = \frac{.0038E}{F}.$$

Assuming the sound source to radiate hemispherically, as is frequently the case because it is associated with a large surface acting as a baffle, the direct sound intensity is:

$$I_D = \frac{E}{2\pi r^2 v},$$

where r = distance from source, in feet,
v = velocity of sound, in feet per second.

In the above expression the direct sound intensity decreases inversely as the square of the distance from the source. This shows that room absorption is effective mainly in reducing the noise from sources at a considerable distance from the observing point, but has relatively little effect on nearby sources.

The curves in Fig. 3 give the variation in the total sound intensity, I_T, with distance from the source for different values of $F = aS/(S - a)$, as computed by means of the above expressions.

Computation of Composite Noise

In the following, the application of the statistical method outlined above is discussed. Since noise measurements are usually expressed in db sound level, it is necessary to change the form of the equations given in the preceding sections. For this purpose equation (5) is rewritten as follows:

$$\frac{I}{I_0} = \frac{m_1}{M}\frac{I_1}{I_0} + \frac{m_2}{M}\frac{I_2}{I_0} + \cdots \frac{m_n}{M}\frac{I_n}{I_0}, \qquad (5a)$$

where I_0 = reference sound intensity.

This equation can also be written

$$\frac{I}{I_0}\frac{M}{300} = \frac{m_1}{300}\frac{I_1}{I_0} + \frac{m_2}{300}\frac{I_2}{I_0} + \cdots \frac{m_n}{300}\frac{I_n}{I_0}. \tag{5b}$$

Equation (5b) is somewhat more convenient in computing than (5a). In this equation a weight factor is associated with each intensity ratio, which is in each case the actual number of peaks divided by the maximum possible number of peaks.

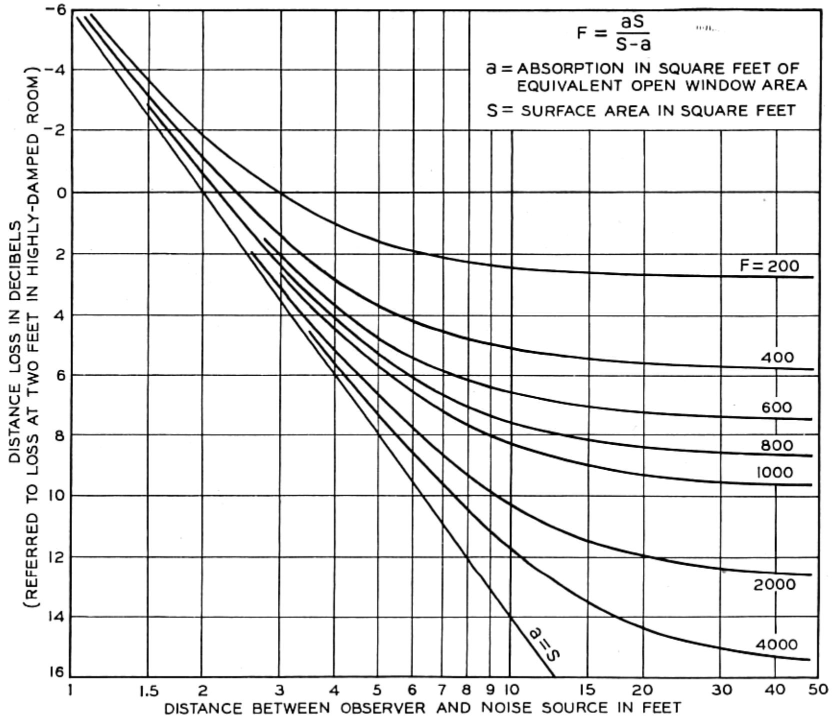

Fig. 3—Loss of intensity with distance from noise source for various amounts of room absorption.

Assuming that the intensity corresponding to the average of the db distribution of each source may be used, the following relations exist for the source noises in db sound level:

$$\left.\begin{aligned} A_1 &= 10 \log_{10} \frac{I_1}{I_0} \\ A_2 &= 10 \log_{10} \frac{I_2}{I_0} \\ &\cdots\cdots \\ A_n &= 10 \log_{10} \frac{I_n}{I_0} \end{aligned}\right\} \tag{6}$$

and for the average composite noise in db sound level:

$$A = 10 \log_{10} \frac{I}{I_0}. \tag{7}$$

It is usually convenient to use logarithmic weight factors

$$\left.\begin{aligned} w_1 &= 10 \log_{10} \frac{m_1}{300} \\ w_2 &= 10 \log_{10} \frac{m_2}{300} \\ &\cdots\cdots \\ w_n &= 10 \log_{10} \frac{m_n}{300} \\ w &= 10 \log_{10} \frac{M}{300} \end{aligned}\right\} \tag{8}$$

Figures 4 and 5 permit ready computation of these logarithmic weight factors. The chart in Fig. 5 is based on the relation between M and N given in equation (4b). It should be recalled that the derivation of this equation involved a number of approximations. This expression especially does not apply when one or more of the noise sources are continuous, in which case the exact expression (eq. 4) gives $M = 300$ (for $t_0 = 0$). Hence $w = 0$ in this case.

The terms of equation (5b) then can be rewritten in logarithmic form by using equations (6), (7) and (8), as follows:

$$\left.\begin{aligned} A_1 + w_1 &= 10 \log_{10} \frac{m_1}{300} \frac{I_1}{I_0} \\ A_2 + w_2 &= 10 \log_{10} \frac{m_1}{300} \frac{I_2}{I_0} \\ &\cdots\cdots\cdots \\ A_n + w_n &= 10 \log_{10} \frac{m_n}{300} \frac{I_n}{I_0} \\ A + w &= 10 \log_{10} \frac{M}{300} \frac{I}{I_0} \end{aligned}\right\} \tag{9}$$

This gives the following formula:

$$10^{\frac{(A+w)}{10}} = 10^{\frac{(A_1+w_1)}{10}} + 10^{\frac{(A_2+w_2)}{10}} + \cdots 10^{\frac{(A_n+w_n)}{10}}, \tag{10}$$

from which the average composite noise A can be found.

The application of this expression is materially simplified by the use of the chart shown in Fig. 6. Power addition of a number of components may be carried out with this chart by first adding two components, then adding the resultant to a third component and continuing until all components have been summed up. Incidentally,

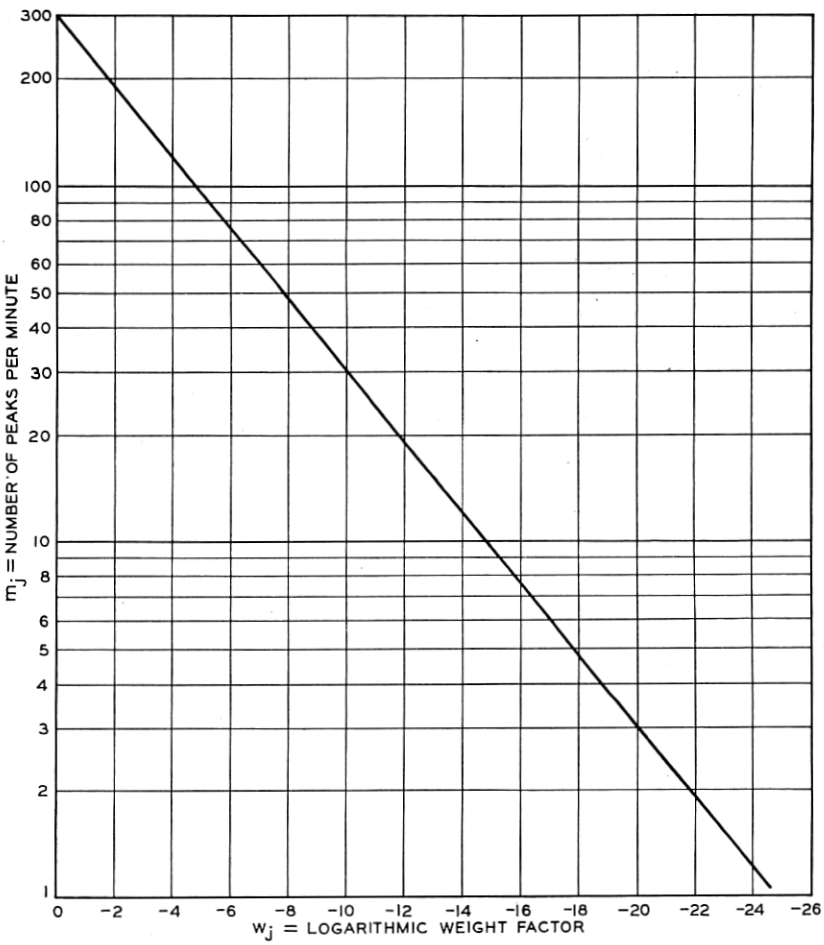

Fig. 4—Relation between peaks per minute (m_j) produced by a noise source and its logarithmic weight factor (w_j).

the chart shows that the contribution to the composite noise from a source whose weighted intensity ($A_1 + w_1$) is 20 db or further below that of another noise source ($A_2 + w_2$) is negligible.

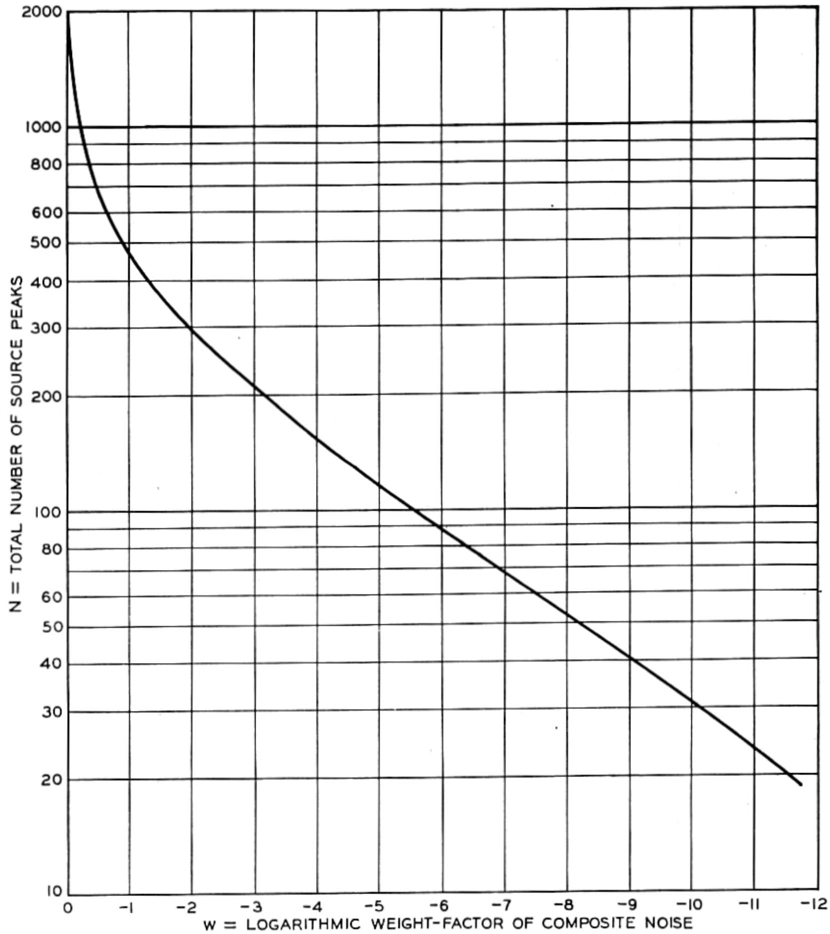

Fig. 5—Relation between total number of peaks per minute (N) and the logarithmic weight factor of composite noise (w).

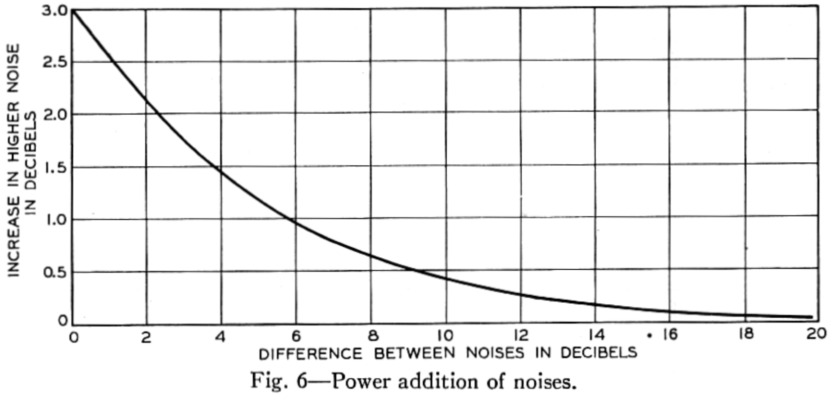

Fig. 6—Power addition of noises.

Applications

In the following, several applications of the theory are made to illustrate its practical usefulness.

I. The composite noise in a typing room is computed. This computed noise is compared with actual measurements. The effect of increased room absorption is discussed.

II. The effect on the composite noise of installing additional office equipment is computed for the two cases where this equipment produces a continuous noise and where its noise is intermittent.

III. The maximum permissible noise from added equipment is determined on the basis that the composite noise level shall not be increased by more than 0.5 db.

Problem I

For the purpose of computing the noise at a given location in the typing room, the following information was obtained:

A distribution of the noise from a typical typewriter was measured at a distance of 2 feet from the type bar guide while the machine was being operated at a normal rate. This is shown by Curve *A* of Fig. 1.

A location was chosen as a point of observation, and the distances between it and the typing desks were measured.

Estimates of the time spent in typing at each desk were obtained which, taken together with data on average typing speeds, gave information on the number of typing peaks produced per minute at each desk.

Computation of the absorption of the room using the usual values of absorbing coefficients [5] gave a value of 650 units for F.

Noise due to other sources, such as conversation and street noise, was negligible in this room.

The table shown below was then prepared.

In this table Column 2 gives the average noise A_j' produced by each of the sources at 2 feet distance. This value is the median point of Curve *A* in Fig. 1. Column 3 is the average number of source peaks per minute m_j produced at each desk. Column 4 is obtained from Column 3 by using Fig. 4. The total number of source peaks is $N = 750$, and from Fig. 5 the composite noise weight factor $w = -0.4$ db. The distances between the observing position and each source are given in Column 5 and the losses in db due to these distances are given in Column 6. These values were obtained from Fig. 3 for a value of $F = 650$. Column 7 is obtained by subtracting the losses of Columns 4 and 6 from the values of Column 2.

Adding the values of Column 7 successively on a power basis by means of the curve in Fig. 6 gives $A + w$ from which is obtained the total composite noise $A = 69.7$ db sound level. This differs by approximately 1 db from the average of the measured composite noise distribution shown by Curve B of Fig. 1.

The effect of sound treatment on the walls and ceiling in reducing the typing room noise may readily be calculated by means of the curves in Fig. 3. Supposing that the added absorption raises the value of F from 650 to 2000 units, this figure shows that noise produced by sources 20 feet or more away from the observing point would be reduced by approximately 5 db. At shorter distances the reduction would be less. For the observing position here considered, a computation similar to that carried out above indicates that the composite noise level would be reduced about 3 db by the added absorption in the room.

TABLE

(1) Source No.	(2) A_j' = Average Source Noise at 2 ft. — db Sound Level	(3) m_j = Source Peaks per Minute	(4) w_j = Freq. Weight Factor — db	(5) Distance from Source — Feet	(6) Intensity Loss vs. 2 Feet — db	(7) $A_j + w_j$ = Weighted Source Noise at Observing Position — db Sound Level
1	71.9	105	−4.5	18	−7.4	60.0
2	71.9	90	−5.2	13	−7.2	59.5
3	71.9	90	−5.2	9	−6.7	60.0
4	71.9	120	−4.0	9	−6.7	61.2
5	71.9	120	−4.0	7	−6.0	61.9
6	71.9	40	−8.8	7	−6.0	57.1
7	71.9	65	−6.6	7	−6.0	59.3
8	71.9	120	−4.0	7	−6.0	61.9

Total Source Peaks: $N = 750$ Power Addition $A + w = 69.3$ db (Fig. 6)

$w = -0.4$ db (Fig. 5) $A = 69.7$ db sound level.

Problem II

A piece of office machinery, such as an addressing or copying machine, which produces an average sound level of 75 db at 2 feet distance, is to be installed in the typing room considered in Problem I, 20 feet away from the observing position. How much will the composite noise level be raised?

(*a*) *The machine produces a steady noise.* The new value for the number of composite noise peaks is then 300 and the weight factor of this noise is zero. The distance loss of the machine noise (for $F = 650$) is -7.5 db from Fig. 3. Hence, the weighted value of the noise from the new machine at the observing position is:

$$75 - 0 - 7.5 = 67.5 \text{ db sound level.}$$

Adding this figure to the weighted value of the existing composite noise ($A + w = 69.3$ db) on a power basis gives the new composite noise value of 71.5 db sound level (the new weight factor being zero). Hence, the composite noise at the listening position is increased 1.8 db by the machine.

(*b*) *The machine produces noise intermittently.* The increase in the composite noise level will not be as great in this case as in the preceding case. For example, assuming the rate to be 100 peaks per minute, the new value of N will be 850 peaks per minute and the corresponding weight factor from Fig. 5 will be − 0.3 db. For the noise from the new machine, the weight factor (by Fig. 4) is − 5.0 db. The distance loss as before will be − 7.5 db. The weighted value of the machine noise at the observing position is then:

$$75 - 5.0 - 7.5 = 62.5 \text{ db sound level.}$$

Adding this figure on a power basis to the weighted value of the existing composite noise, 69.3 db, results in a new weighted composite sound level, $A + w = 70.1$ db. Since $w = -0.3$ db, this gives $A = 70.4$ db. Hence, the composite noise is increased 0.7 db by the intermittent machine noise.

Problem III

What is the maximum permissible noise, measured at 2 feet, which the machine considered in Problem II, may produce without raising the composite noise in the typing room by more than 0.5 db?

(*a*) *The machine produces a steady noise.* In this case, the composite noise has 300 peaks and its weight factor is zero. The existing composite noise was 69.7 db sound level (see Problem I). The maximum permissible value of the new composite noise level is consequently

$$A = 69.7 + 0.5 = 70.2 \text{ db sound level.}$$

Let the unknown machine noise be A_9 (its weight factor is zero), and since for the existing composite noise $A + w = 69.3$, equation (10) gives:

$$10^{\frac{70.2}{10}} = 10^{\frac{69.3}{10}} + 10^{\frac{A_9}{10}}.$$

Entering the ordinate of Fig. 6 at the value of $70.2 - 69.3 = 0.9$ db, the chart indicates that A_9 must be 6.3 db below 69.3. Hence $A_9 = 63$ db sound level at the observing position.

The distance loss for 20 feet is $-$ 7.5 db. The machine then could produce a noise of:

$$63.0 + 7.5 = 70.5 \text{ db sound level}$$

at 2 feet distance without raising the composite noise level by more than 0.5 db at the observing position.

(*b*) *The machine produces noise intermittently.* The solution of the problem in this case follows the same lines as in Part (*a*) except that the weight factors are changed. The rate for the new machine noise, A_9, is assumed to be 100 peaks per minute, so that $w_9 = -5.0$ db, as in part (*b*) of Problem II. The maximum permissible value of the new composite noise is 70.2 db sound level (as before) but its weight factor now is $-$ 0.3 db as in part (*b*) of Problem II. The weighted value of the existing composite noise as before is 69.3 db sound level. Equation (10) then gives:

$$10^{\frac{(69.9)}{10}} = 10^{\frac{69\,3}{10}} + 10^{\frac{(A_9-5.0)}{10}}.$$

From Fig. 6 it is found that for a value of $69.9 - 69.3 = 0.6$ on the ordinate, the abscissa is 8.3 db. Hence, $A_9 - 5.0$ must be 8.3 db below 69.3 or $A_9 = 66.0$ db sound level at the observing position. Applying the same distance loss as before, the machine could produce a noise of 73.5 db sound level at 2 feet without increasing the composite noise level by more than 0.5 db at the observing position.

From the computations, then, it may be expected that adding a steady noise will increase the general noise level more than adding an intermittent noise having the same average value, when there are a number of sources operating. That this is actually so can readily be verified by sound level measurements. As has been stated, sound level measurements under most conditions are directly related to the effects of noise upon the individual exposed to it, and the method described provides a convenient and reasonably reliable way of computing such readings and thereby makes possible the engineering analysis of noise problems.

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