April 12, 1932. W. A. MacNAIR 1,853,912

STUDIO FOR ACOUSTIC PURPOSES

Filed Dec. 12, 1929

FIG. 1

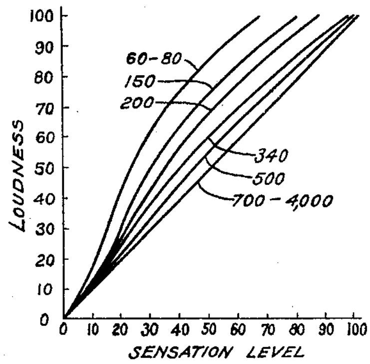


FIG. 2

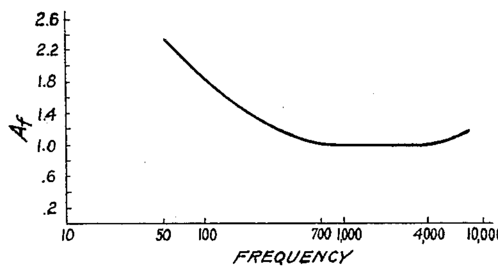


FIG. 3

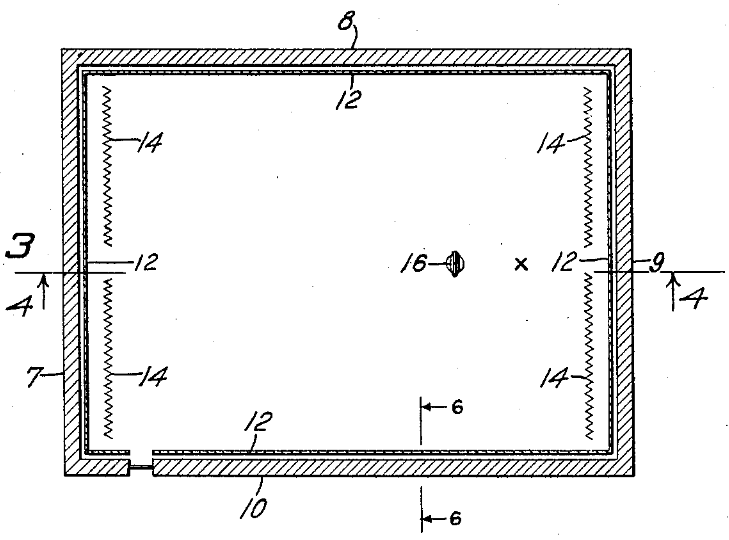


FIG. 4

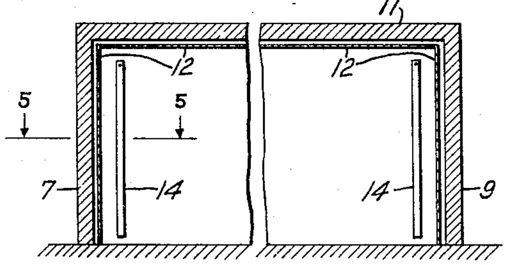


FIG. 5

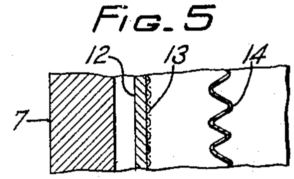
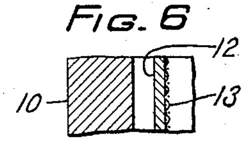


FIG. 6



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1,853,912

UNITED STATES PATENT OFFICE

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STUDIO FOR ACOUSTIC PURPOSES

Application filed December 12, 1929. Serial No. 413,538.

This invention relates to acoustically treated rooms such as auditoriums and sound recording, sound reproducing and broadcasting studios.

Heretofore, it has been the aim to design acoustic studios and other rooms where acoustics are involved so that they had the same reverberation time for all frequencies. While this arrangement is satisfactory for the middle range of frequencies as between 700 and 4000 cycles per second it provides an undue amount of absorption for sound energy in the frequencies above and below this range.

It is the object of this invention therefore to overcome this undue absorption in the lower and upper frequency ranges by arranging the damping material in the studio so as to provide the proper amount of sound absorption at all frequencies of importance in speech and music.

Specifically, the invention provides for obtaining the proper reverberation time at all frequencies by applying the damping material to the walls of the studios or otherwise arranging it therein, so that the loudness of all pure tones generated in the studio decays at the same rate for all frequencies. This is accomplished by arranging the damping or sound absorbing material so that the reverberation time is substantially constant over the middle range of frequencies, for example, between 700 and 4000 cycles per second and gradually increases as the frequency decreases below this range and as it increases above it.

The term acoustic studio as used herein comprehends sound recording and sound reproducing studios, auditoriums, theatres, broadcasting studios and such rooms as usually require damping for acoustic reasons.

Referring to the drawings Fig. 1 represents a family of curves showing for different frequencies the variation in loudness with variation in sensation level. These curves are a reproduction of Fig. 108 on page 230 of "Speech and Hearing" by Dr. H. Fletcher.

Fig. 2 is a curve showing the variation of the reverberation period with frequency according to the invention.

Fig. 3 represents diagrammatically a plan view of a studio damped in accordance with the present invention.

Fig. 4 is a condensed sectional view on lines 4—4 of Fig. 3.

Fig. 5 is a fragmentary section enlarged showing the arrangement of the damping material at 5—5 of Fig. 4.

Fig. 6 is an enlarged fragmentary section showing an arrangement of the damping material at 6—6 of Figs. 3 and 4.

The curves shown in Fig. 1 were plotted from the average results of observations made by a large number of persons in comparing a test tone at different intensities with other tones of various frequencies adjusted to give the same loudness effect as the test tone. The sensation level of any sound reaching the ear is the number of sensation units, or decibels, it is above the threshold level for audition. The loudness of a pure tone having a zero reference pitch, that is, corresponding to a frequency of 1000 cycles per second has been chosen to be equal to the sensation level of this tone. With this as a reference tone the loudness of any other sound, whether a pure tone having a different pitch, a musical tone or any other complex sound, is measured by the loudness of the reference tone which sounds equally loud as judged by the average normal ear. Zero loudness at all frequencies corresponds to the well known minimum or threshold value for pure tones. A curve showing the values for all frequencies is reproduced on page 141 of Dr. Fletcher's book. If P_1 and P_2 are two different amounts of power being compared, then the difference in the power level N expressed in bels is given by the equation

$$N=\log_{10}\frac{P_1}{P_2}.$$

The decibel (db.) is one tenth of a bel.

It will be noted from the curves in Fig. 1 that for frequencies between 700 and 4000 cycles per second any variation in sensation level produces an equal variation in loudness. Outside this range, however, any change in sensation level gives a greater change in loudness. It will be evident that for the purpose of illustrating this invention the curves may be represented by straight lines without introducing observable errors. With this assumption this family of curves may then be represented by the expression $L_t = A_f S_t$ where A_f is the slope of the curve for the frequency f, L_t the loudness and S_t the sensation level at any time t after the source is cut off. If, for example, we wish to adjust the absorption of the room so that the loudness of all pure tones will decay, say 60 db. per second, it will be seen that the sensation level must drop 60 db. per second for frequencies between 700 and 4000 cycles per second and for other frequencies it must drop

$$\frac{60}{A_f}\text{ db.}$$

per second. In other words, if the reverberation time for frequencies between 700 and 4000 cycles per second is one second then outside of this band it should be A_f seconds.

Fig. 2 is a curve showing the plot of A_f against frequency and illustrates how the reverberation time must vary with frequency in order that the loudness of pure tones of all frequencies shall have the same rate of decay.

In Figs. 3 to 6, inclusive, which illustrate a typical studio embodying the invention, 7, 8, 9 and 10 represent the side walls of the studio chamber and 11 the ceiling. Disposed in front of the side walls and below the ceiling and spaced therefrom is the layer of insulating material 12 approximately one inch thick, to the face of which is applied a layer of burlap 13. Draped in front of this and spaced therefrom on walls 7 and 9 only, in the case shown, is a layer of textile material 14 such as monk's cloth having a gathering of approximately 25 per cent of its surface.

A performance may be given at any position as indicated by "X" in front of which is the usual microphone 16, for picking up the sound vibrations. The microphone may be connected to any suitable transmission and translating system.

That the value of the reverberation time varies with the volume of the studio is well known but the curve of Fig. 2 is identical in form for all embodiments, the value of the ordinates only changing. For example, Fig. 2 shows an optimum reverberation time of one second at 1000 cycles for a given volume. If the volume is increased so that the optimum reverberation time is two seconds then the values of all ordinates will be increased accordingly, doubled in this case. The optimum time for any volume at 1000 cycles may be determined from the following formula:

$$\log V = 10.4 \times \log T - \frac{6.35}{\sqrt{T}},$$

where V is the volume in cubic feet and T the optimum reverberation time at 1000 cycles per second.

In practicing the invention herein described a reverberation time meter, such as shown in Patent 1,722,027, E. C. Wente, July 23, 1929, will be found very convenient. By its aid the damping or sound absorbing material on the walls may be adjusted until the reverberation time is of the form shown in Fig. 2.

Although a specific arrangement of well known sound absorbing materials has been shown for the purpose of illustrating one embodiment of the invention it is evident that various arrangements of other suitable damping materials will give the same results. The invention therefore contemplates any arrangement of materials in any size room, such as will give a reverberation time vs. a frequency characteristic of the type shown in Fig. 2. With the aid of a suitable reverberation meter this may be readily accomplished.

What is claimed is:

1. An acoustic studio comprising a chamber and damping means therein for controlling the persistence of sound waves, said damping means being so constructed and arranged that the loudness of all pure tones decays at the same rate for all frequencies.

2. An acoustic studio comprising a chamber and damping means therein of such a nature that the reverberation time for frequencies between 700 and 4000 cycles per second is substantially constant and gradually increases as the frequency decreases below said range.

3. An acoustic studio comprising a chamber and damping means therein of such a nature that the reverberation time is constant for a substantial range of frequencies and increases for frequencies outside of said range.

4. The method of treating an acoustic studio which consists in arranging sound absorbing material therein so that the loudness decay is substantially the same for all frequencies.

5. The method of controlling the acoustics of sound chambers which consists in absorbing sufficient sound wave energy at frequencies between 700 and 4000 cycles per second to give the optimum reverberation time at 1000 cycles per second for this frequency range and an increased value below this range.

6. The method of treating an acoustic studio which consists in arranging damping material therein so that the reverberation time between approximately 700 and 4000 cycles per second corresponds to a predetermined value for 1000 cycles per second and increases as the frequency decreases below this range.

7. The method of treating an acoustic studio which consists in arranging damping material therein so that the reverberation time for the middle range of frequencies of importance in speech and music corresponds

to a predetermined value for 1000 cycles per second and increases for frequencies outside of the middle range.

8. An acoustic studio comprising a chamber and sound absorbing material on the walls thereof, said sound absorbing material being of such a nature that the loudness of all pure tones decays at the same rate for all frequencies of importance in music and speech.

9. An acoustic studio comprising a chamber and a plurality of layers of sound absorbing material spaced parallel to the walls of said chamber, said layers being so spaced with respect to the walls and each other that the loudness of all pure tones decays at the same rate for all frequencies of importance in speech.

10. An acoustic studio comprising a chamber and damping material in spaced relation with the walls thereof, the damping material and the spacing being such that the reverberation time for frequencies between 700 and 4000 cycles per second is substantially constant and gradually increases as the frequency decreases below 700 cycles per second.

In witness whereof, I hereunto subscribe my name this 11th day of December, 1929.

WALTER A. MACNAIR.