Aug. 18, 1942. F. E. TERMAN 2,293,181

SOUND ABSORBING APPARATUS

Filed July 17, 1940 2 Sheets-Sheet 1

FIG. 1.

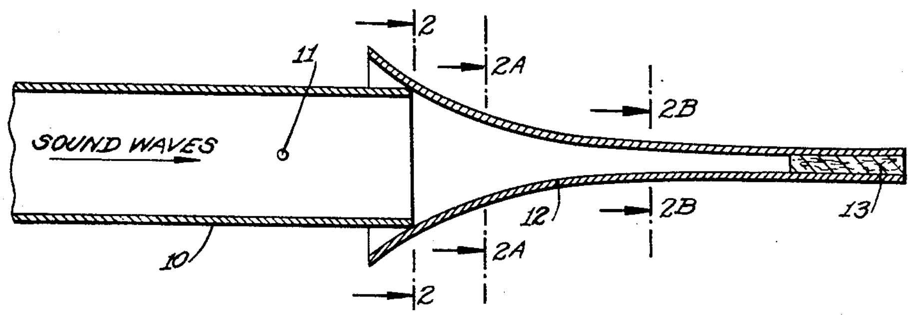


FIG. 2.

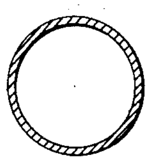


FIG. 2A.

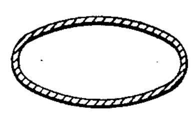


FIG. 2B.

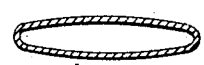
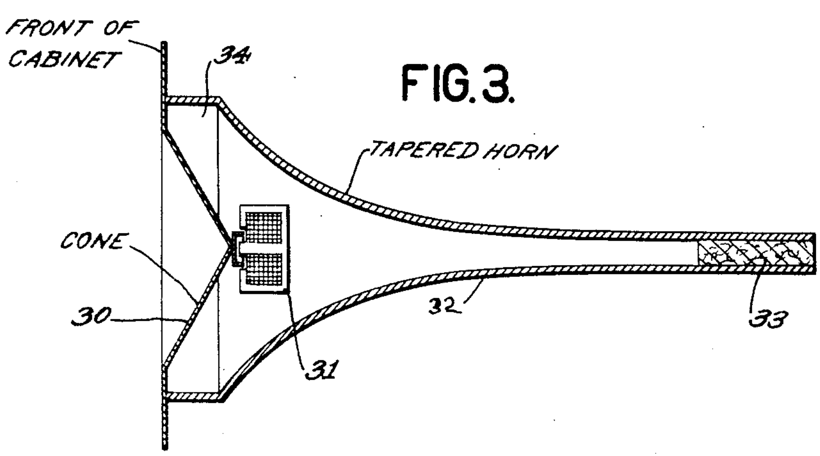


FIG. 3.



INVENTOR.
FREDERICK E. TERMAN

BY R. C. Hopgood

ATTORNEY.

Aug. 18, 1942. F. E. TERMAN 2,293,181

SOUND ABSORBING APPARATUS

Filed July 17, 1940 2 Sheets-Sheet 2

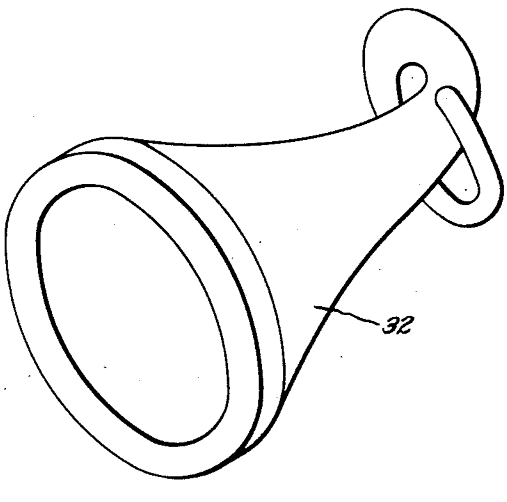


FIG. 4.

FIG. 5.

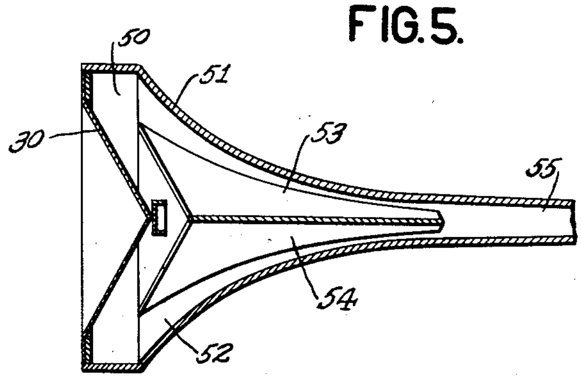
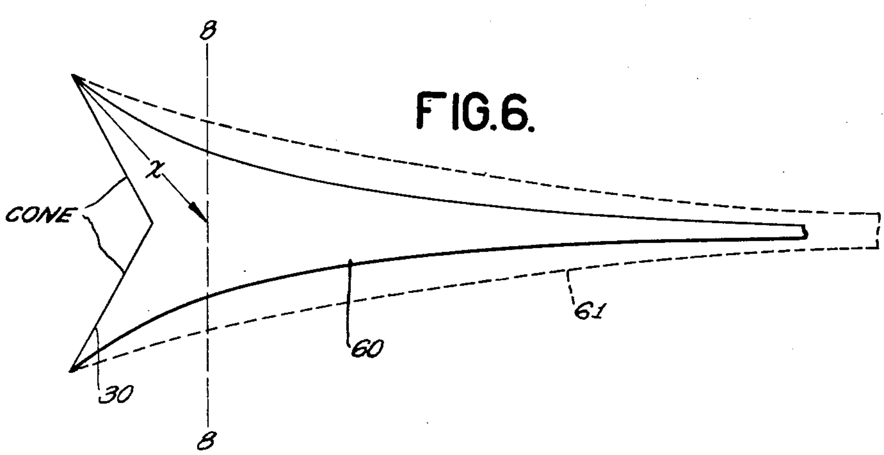


FIG. 6.



INVENTOR.
FREDERICK E. TERMAN
BY R. C. Hopgood
ATTORNEY.

Patented Aug. 18, 1942 2,293,181

UNITED STATES PATENT OFFICE

2,293,181

SOUND ABSORBING APPARATUS

Frederick E. Terman, Stanford University, Calif., assignor to International Standard Electric Corporation, New York, N. Y., a corporation of Delaware

Application July 17, 1940, Serial No. 345,943

11 Claims. (Cl. 181—31)

My invention relates to sound absorbing systems and more particularly to a system of sound absorption which requires a minimum of absorbing material.

One object of my invention is to provide means by which the backside radiation from a loud speaker can be completely absorbed thereby eliminating the necessity of a baffle.

Another object of my invention is to provide means by which sound measurements can be made without disturbance from reflected waves.

The principle of operation which is made use of to accomplish these results is to transform the sound waves into waves having much higher particle velocity, and then to use this high particle velocity to increase the absorption. This is accomplished by causing the sound wave to enter the open end of a horn that is so tapered that no reflection takes place. As the sound wave travels down the horn to sections of progressively smaller cross-section the particle velocity is increased and reaches a very high value at the throat. A small amount of absorbing material placed in the throat of the horn will then absorb the energy very completely. This results from the fact that the absorption of energy is a result of vibrating particles striking against fibers of the absorbing material and losing kinetic energy. Inasmuch as the kinetic energy to be lost varies as the square of the velocity it is apparent that a given amount of energy in a sound wave is much more readily absorbed in the throat than is the same energy of the original wave before entering the open end of the horn.

It is clear that instead of inserting separate sound absorbing material the walls of the horn may be made of material absorbent of sound.

Other advantages and objects of my invention will be apparent from a particular description thereof made in connection with the accompanying drawings, in which

Fig. 1 illustrates the principle of my invention applied to the calibration of microphones;

Figs. 2, 2A and 2B illustrate various types of cross-sections which may be applied to the horn, for instance cross-sections taken at lines 2—2, 2A—2A, 2B—2B of Fig. 1;

Fig. 3 illustrates schematically the sound absorbing system in accordance with my invention applied to a loud speaker arrangement;

Figs. 4 and 5, illustrate modifications of the speaker construction illustrated in Fig. 3; and

Fig. 6 illustrates a still further feature of my invention whereby the slope of the horn may be varied.

In Fig. 1 of my invention a tapered horn is shown as terminating a sound passage for the purpose of calibrating a microphone. In this arrangement I provide a tube 10 through which the sound waves pass. Mounted within this tube 10 is the instrument 11 which is to be calibrated. This may be a microphone or a Rayleigh disc. A discussion of calibration of microphones by use of a Rayleigh disc is set forth fully in "Radio Engineering" by applicant, first edition, published by McGraw-Hill Book Co., Inc., in 1932, on pages 665–666.

At the open end of tube 10 is provided a tapered horn 12. The sound waves traveling down the tube 10 in the direction indicated by the arrow reach the open end of the horn 12. These waves enter the horn with negligible reflection and reach the small end thereof where they are completely absorbed, for instance by sound absorbing material 13. The result is, therefore, equivalent to placing the microphone or Rayleigh disc 11, in a tube of infinite length without the necessity of making the actual physical length particularly great.

In the construction of tapered horn 12, it is preferable that the taper be such that the cross-section follows the usual exponential law, since this way there is a minimum of disturbance introduced by the presence of the horn. The rate of taper of the horn determines the lowest frequency of sound waves that will travel therethrough without partial reflection. The more gradual the taper the lower will be the minimum frequency at which appreciable reflection is avoided.

The shape of the cross-section of the horn is relatively unimportant provided abrupt changes in shape are avoided and provided the area varies in accordance with the desired law. The horn then need not have a uniform shape cross-section. This fact may be taken advantage of to simplify the structural problems since the horn may then be tapered with varying cross-sections, as indicated in Figs. 2, 2A and 2B. Thus, the cross-section may be reduced merely by flattening the horn, as indicated. After the cross-sectional area is reduced to a suitable constant value, it may be filled with sound absorbing material to dissipate the sound energy. It is immaterial whether the small end of the horn is open or closed, since, if the absorption is great a negligible energy is available to be reflected and a negligible part of this negligible energy will be able to find its way back through the absorbing material to the large end of the horn.

In Fig. 3 is illustrated an application of the absorbing horn in accordance with my invention for eliminating the backside radiation interference from a loud speaker. In this figure is shown an ordinary dynamic speaker having a vibrating diaphragm 30 operated by means of speaker magnet 31. In the ordinary dynamic speaker the cone radiates sound waves on both the front and back surfaces. These radiations are of nearly equal intensity and start away from the cone at 180° out of phase. The observed sound is the resultant of these two radiations. When the shortest air route from the back is less than a quarter wavelength, the front and back radiations combine to virtually cancel each other because of the large phase difference. This action is always present at lower frequencies since these are the frequencies for which the wavelength is greatest. As a result the ordinary speaker arrangement always has a cut-off frequency below which satisfactory response cannot be obtained.

The usual method applied for minimizing this action is to lengthen the path from the back to the front of the speaker by use of a baffle which may be formed as part of the cabinet. The size of baffle or cabinet required to do this at the lower frequencies which are considered essential to high fidelity reproduction is inconveniently large and makes it impossible to obtain satisfactory reproduction of the lower frequencies with compact radio receivers.

At the higher frequencies the backside radiation produces interference effects with the front side radiations which are very critical with respect to frequency and which depend, among other things, on the position of the loud speaker with respect to walls and other surfaces. A particularly important effect of this character is resonances formed by the open back of the cabinet functioning as a sort of organ pipe to reenforce selectively certain notes while selectively discriminating against others. With an application of the sound absorbing device of my invention, as shown in Fig. 3, the loud speaker comprising cone 30 and magnet 31 is so arranged that the backside radiation enters the large end of a tapered horn 32. Sound waves progress down this horn until they reach the throat portion where they are readily absorbed by suitable absorbing material, such as 33. In the practical example illustrated in the figure, a short tube 34 is provided back of the speaker followed by the tapered horn 32.

In order to reduce the overall dimensions of the tapered horn, the throat portion thereof may be coiled, as indicated in Fig. 4, and the end of this coiled portion may be filled with sound absorbing material, such as illustrated in Fig. 3. The throat portion of this horn may be either of constant cross-sectional form or may be progressively flattened as shown in Figs. 2 to 2B.

A modification of the tapered horn construction is illustrated in Fig. 5. By this arrangement the space in back of speaker diaphragm 30 is divided into separate segments indicated at 50, 51 and 52. Each of these segments is then provided with separate walls 53, 54, forming in effect separate tapered horns. If desired these tapered horns may be terminated in a common throat portion 55. It is obvious that various other modifications common within the general spirit of this disclosure will suggest themselves to those skilled in the art.

The size of the loud speaker, as shown in Figs. 3 to 5, may be reduced by taking advantage of a further fact. This fact is that sound energy may be transmitted by pressure in chambers in which the maximum dimensions do not exceed a quarter of a wavelength. This makes it possible to taper the portion of the absorbing horn adjacent the large end more rapidly than the exponential law would lead one to believe permissible, while the remaining or second portion between the large end and the throat can be tapered substantially in accordance with the exponential law. The criterion controlling the taper may be more rapidly understood by reference to Fig. 6. Assume that the distance x from the most distant part of the cone 30 to the cross-sectional line 8—8, in Fig. 6, is approximately a quarter of a wavelength at the frequency to be considered. Then, the part of the horn 60 to the right of line 8—8 may have a rate of taper gradual enough to permit this frequency to propagate to the small end of the horn without reflection. However, the region to the left of line 8—8 may have a greater rate of taper since energy can be transmitted at this frequency by pressure to line 8—8. Inasmuch as the higher frequencies (shorter wavelengths) can tolerate a more rapid taper than the lower frequencies, it is apparent that as the large end of the horn is approached the rate of taper can be markedly increased. The diminished size of the horn over that which would be necessary were no compression transmission utilized in the large end of the horn is shown by the dotted line horn arrangement 61 of Fig. 6. The outline 61 indicates the normal uniform taper which would be necessary, showing that the horn without the more rapid curvature at the entrance thereof would necessarily be considerably larger in order to increase the particle velocity of the sound waves to the desired extent.

The principles of my invention outlined above show that it is possible to suppress radiation from the back of the loud speaker with a relatively compact device. This permits the use of a small cabinet in high fidelity receivers and may be used to advantage in connection with loud speakers of small depth. Thus, speakers of this type could be arranged to be hung on a wall something like a picture, the backside of the horn then being coiled in a flat spiral somewhat similar to that shown in Fig. 4. It is clear that the spiral of the horn could be made considerably flatter by commencing this curvature immediately back of the loud speaker instead of only at the end, as shown in Fig. 4.

The device accomplishes the results without introducing any resonance effect modifying the loud speaker characteristics. The action, so far as the speaker diaphragm is concerned, is substantially as though the speaker were mounted in an infinite baffle.

While I have discussed certain preferable forms of my invention in connection with the specific illustration shown in the various figures, it is to be distinctly understood that this description is merely by way of illustration and is not to be considered a limitation on the scope of my invention. What I consider as my invention and desire to obtain patent protection on is embodied in the accompanying claims.

What I claim is:

1. A sound absorbing system comprising a tapered horn with a relatively large input opening and a small throat portion, the taper of said horn being such as to cause substantially no reflection and at least a portion of said horn being tapered in accordance with an exponential law,

whereby sound waves applied at said input opening are increased in particle velocity during progression through said horn, and sound absorbing means at the throat of said horn to absorb the energy of said increased particle velocity waves.

2. A sound absorbing system according to claim 1, wherein said tapered horn comprises a first portion adjacent said input opening having a length not over a quarter wavelength at the lowest frequency to be absorbed having a taper exceeding the exponential law curve for such a system, and a second portion joined to the small end, said second portion having a taper substantially following said exponential law.

3. A sound absorbing system according to claim 1, further comprising a source of sound waves, a tubular passage from said source of sound waves to said input opening, and a sound calibrating system suspended in said tubular passage.

4. A loud speaker comprising a sound reproducing diaphragm, and means for absorbing sound waves from the rear side of said diaphragm comprising a tapered horn having a relatively large input opening for receiving sound waves, produced on the rear side of said diaphragm, said horn being tapered in cross section to a relatively small throat portion the rate of taper per unit length being proportioned to cause substantially no reflection of the sound waves produced by said diaphragm, and sound absorbing means in the throat portion of said horn to absorb the energy of said sound waves passing through said horn.

5. A loud speaker according to claim 4, wherein said tapered horn comprises a first portion adjacent said input opening having a length not over a quarter wavelength at the lowest frequency to be absorbed having a taper exceeding the exponential law curve for such a system, and a second portion joined to the small end, said first portion having a taper substantially following said exponential law.

6. A loud speaker arrangement comprising a sound reproducing diaphragm, and means for absorbing sound waves from the rear side of said diaphragm comprising a plurality of tapered horns each having relatively large input openings for receiving sound waves produced by portions of the rear side of said diaphragm, each of said horns being tapered to a relatively small throat portion in such a curve as to cause substantially no reflection of the sound waves produced by said diaphragm, and sound absorbing means at the throat portions of said horns to absorb the energy of said sound waves passing through said horns.

7. A loud speaker comprising a sound reproducing diaphragm, means for absorbing sound waves from the rear side of said diaphragm comprising a tapered horn having a relatively large input opening and a relatively small throat portion, said horn being so disposed that the input opening thereof covers the rear side of the speaker diaphragm, the input opening and the throat portion being connected by a tapered portion with a rate of taper per unit length proportioned so as to reduce to a minimum reflection losses in the horn.

8. A loud speaker comprising a sound reproducing diaphragm, means for absorbing sound waves from the rear side of the diaphragm comprising a tapered horn having a relatively large input opening and relatively small throat portion, said horn being so disposed that the input opening thereof covers the rear side of the speaker diaphragm, and sound absorbing means in the throat portion of said horn to absorb the energy of sound waves passing through the horn, the input opening and the throat portion being connected by a tapered portion with a rate of taper per unit length proportioned so as to reduce to a minimum reflection losses in the horn.

9. A loud speaker of the type which is subject to interference between front diaphragm radiation and rear diaphragm radiation comprising a horn having a relatively large input opening and a relatively small throat portion, a diaphragm substantially covering said input opening, and diaphragm actuating means disposed inside of said horn.

10. A loud speaker of the type which is subject to interference between front diaphragm radiation and rear diaphragm radiation comprising a horn having a relatively large input opening and a relatively small throat portion, a diaphragm substantially covering said input opening, and sound absorbing means in the throat portion of said horn to absorb the energy of sound waves from said diaphragm.

11. A loud speaker having a large surface direct acting diaphragm which is subject to interference between front diaphragm radiation and rear diaphragm radiation, and a baffle effectively to isolate acoustically the front from the rear of the diaphragm, said baffle comprising a tapered horn having its bell portion closely coupled to the rear of the diaphragm and its throat portion connected to the bell portion by a tapered section with the rate of taper per unit length proportioned to reduce to a minimum reflection losses in the horn, and a plug of sound absorbing material located in the throat portion of the horn.

FREDERICK E. TERMAN.