Feb. 26, 1935. E. C. WENTE 1,992,268

ACOUSTIC DEVICE

Filed April 11, 1933

FIG. 1

FIG. 3

FIG. 4

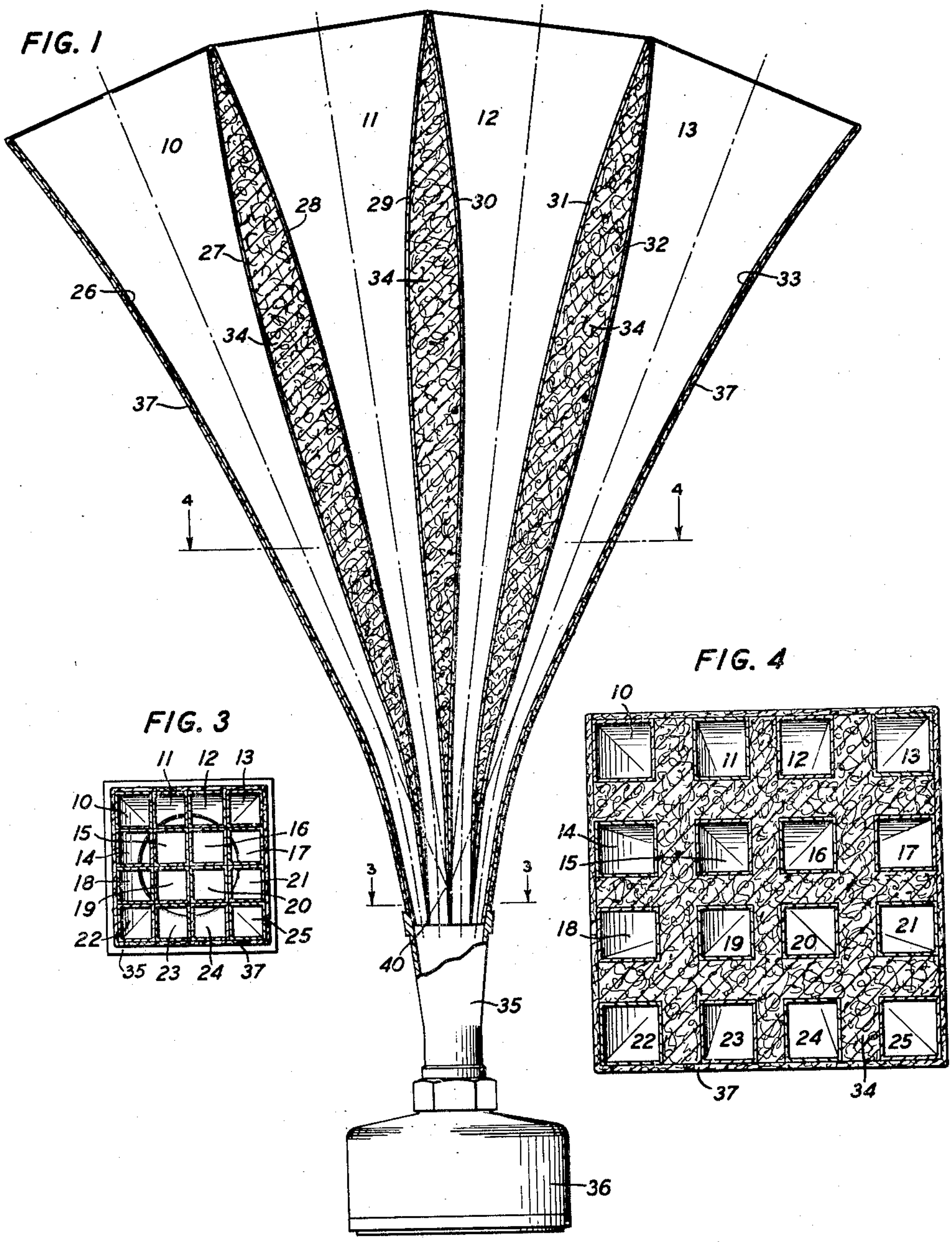
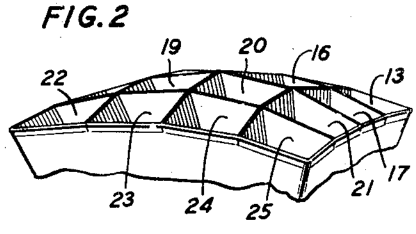


FIG. 2



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ACOUSTIC DEVICE

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Application April 11, 1933, Serial No. 665,547

8 Claims. (Cl. 181—27)

This invention relates to horns and more particularly to horns suitable for the transmission of speech or music such as used with phonograph reproducers and loudspeakers.

An object of the invention is to provide a horn which will give for a wide frequency range a uniform distribution of sound throughout a wide solid angle.

Another object is to provide an acoustic coupler between a diaphragm and free space which will project into the free space sound having an approximate spherical wave front for all frequencies within a wide frequency range.

In accordance with this invention this wide distribution of the sound waves is secured by the use of a large number of channels within the horn having a common throat portion and having their mouth openings contiguous and assembled to define a segment of an approximate spherical surface, the axes of all the channels measured from a given plane wave front in the throat to the mouth being of substantially equal length. With such a construction it follows that the sound waves emitted at the channel outlets will be of the same phase for each frequency so as to simulate a spherical wave front for the emitted sound over a wide frequency range. The greater the number of channels employed for a given solid angle of mouth opening the higher will be the maximum frequency at which this spherical wave front will be secured. In order that the sound density will be the same in each horn over the frequency range of interest the loudspeaking receiver and the common throat portion should be so designed that the sound waves arrive at the horn inlets on a plane wave front.

The channels of the horn are preferably of the exponentially tapering type. It has been found experimentally that for frequencies below a value of about

$$\frac{10^7}{df_0}$$

the wave front at the mouth of a straight exponential horn will be spherical with its center of curvature lying on the axis of the horn, where d is the diameter in centimeters of the mouth opening and f_0 is the cut off frequency. For frequencies above this value the wave at the mouth opening will be approximately planar. The sound density will be approximately uniform over the mouth opening in either case until a frequency four or five times the above value is reached.

The sound wave front at the mouth of a horn built with a plurality of sound channels as above described is thus made up of contiguous areas of spherical waves at the lower frequencies and of planar waves at the higher frequencies. This wave front will produce the same distribution of sound in space as a spherical wave front coincident with the mouth opening provided the departure between the two is nowhere greater than approximately a half of a wave length of any frequency within the transmitted range.

Referring to the drawing,

Fig. 1 represents a view partly in longitudinal section of a horn structure embodying this invention;

Fig. 2 is an end view in perspective of the sound outlet of the structure of Fig. 1;

Fig. 3 is an enlarged cross-section of the structure of Fig. 1 at the sound inlets on the line 3—3 of Fig. 1; and

Fig. 4 is a cross-section of the structure of Fig. 1 on the line 4—4 taken at a point intermediate the sound inlet and sound outlet.

The particular form of this invention chosen for illustration comprises sixteen horns 10 to 25 inclusive, attached to a common throat portion 35 with their axes angularly disposed with respect to each other. The horns are arranged in four rows with four horns in each row, each horn preferably having its cross-sectional area increasing logarithmically at the same rate throughout its length from inlet to outlet, all horns having the same exponential taper. The combined inlets for the sixteen horns as shown in the enlarged sectional view of Fig. 3 are compactly assembled together in four rows the side walls of each horn preferably being tapered at its inlet and the sixteen inlets fastened firmly together as by soldering. The combined sound receiving end fits snugly into the square ended common throat portion 35 which is circular in cross-section at its other end for attachment to an electrical loudspeaking receiver 36. A type of receiver which has been found particularly suitable for use with this horn is that described in my copending application Serial No. 663,133 filed March 28, 1933.

The outlets of the horns are shown in perspective in Fig. 2 and from this figure it will be apparent that the outlets lie in a segment of a spherical surface subtending a solid angle of about 60°. The center for this spherical surface will be the virtual source of the emitted sound and this center preferably lies at the intersection of the walls of the four central horns 15, 16, 19 and 20 at their inlets or as near thereto as practicable from a mechanical standpoint. The axis of each horn is straight except for the portion near its inlet but if all the axes are extended in a straight line from the horn outlets they will all meet at the center which defines the spherical surface segment of the outlets. Point 40 in Fig. 1 represents this virtual source of sound and the dotted lines in Fig. 1 representing the axes of the horns have also been extended to show their convergence on point 40. In view of the relatively large radius of curvature compared to the outlet width of each horn it will generally be found acceptable to have all four corners of each horn at the outlets lie in the described spherical surface segment with straight edges of the walls between said corners, but these edges may also be curved to terminate in the same spherical surface portion as the corners.

It will be noted from Fig. 2 that the horn outlets are compactly arranged with juxtaposed side walls to give substantially a single mouth opening except for the edges of the walls. The edges of contacting walls at the mouth may be riveted or otherwise fastened together.

In order to prevent any substantial vibration of the horn walls and to avoid interference between adjacent horns the horns are preferably, for the greater portion of their length, embedded in vibration damping material 34 such as felt. This is clearly shown in Fig. 4 which is a sectional view intermediate inlet and outlet. The vibration absorbing material is also shown in Fig. 1 between walls 27, 28, walls 29, 30 and walls 31, 32. The outside of the composite horn structure except fot inlet and outlet is preferably covered with a layer 37 of felt or other sound absorbing material for reducing wall vibration. This may be in the form of a solid layer entirely surrounding the horn and closing the gaps between adjacent horns.

As previously stated, each horn is preferably square in cross-section with an exponential taper for all four sides of each horn, each horn preferably having the same exponential taper wtih substantially the same size of inlet and outlet. Thus, walls 26, 27 of horn 10 are shaped logarithmically as well as the other two side walls of horn 10 not shown in Fig. 1. Outside horns such as horns 10 and 13 have a greater deflection from the axis of throat 35 than the inner horns 11 and 12 to allow the proper mouth opening for each horn. However, the taper of each horn being the same it follows that the speed of propagation of sound waves is the same in each horn. The electrical loudspeaker receiver 36 should preferably be of such a type that the sound waves projected into the throat 35 have a planar wave front as the horn inlets are approached, to insure that each horn inlet will receive the same sound density per unit area for all frequencies in the range to be reproduced. Since all the horns are of equal axial length measured from inlet to outlet it follows that at the horn outlets the sound waves emitted by each horn will be in phase with the sound waves emitted by the other horns to give a spherical wave front at the combined mouth for a frequency range of a width based upon considerations to be described later.

The following design has been found suitable for the transmission of a frequency range from 300 cycles to above 12,000 cycles employing sixteen horns subtending a solid angle of approximately 60°. The length of each horn from inlet to outlet was approximately 26 inches with a length of approximately 25 inches from each outlet to the point 40, the virtual source of the sound and the center of curvature for the spherical surface segment defined by the horn outlets. Each horn was approximately 7 inches square at its outlet and between 0.5 inch and 0.6 inch square at its inlet. If a larger number of horns were used for the same solid angle the mouth and throat openings would of course, be correspondingly reduced in cross-sectional area. Each horn was preferably made of thin sheet metal about 0.02 inch in thickness.

Such a composite horn as illustrated in the drawing gives a much wider spread of the sound waves of high frequencies than would be secured by a single horn having a mouth opening equal to the combined mouth opening of the sixteen horns. In the first place, the fact that each of the sixteen inlets receives its proportionate share of the sound energy over the entire frequency band to be transmitted, it follows that each horn directs its sound energy over a different solid angle from the other horns and will, therefore, assist in spreading the emitted sound energy over the sound field represented by the solid angle subtended by the horn outlets. The fact that the outlets of all the channels form a spherical surface segment will give an approximate spherical wave front for all frequencies up to 12,000 or 15,000 cycles per second. With a cut off frequency of 200 cycles and a channel outlet of 7 inches as above described we find from the expression

$$\frac{10^7}{df_0}$$

that for all frequencies below about 3,000 cycles the wave front from each channel will be spherical with its center of curvature lying on the axis of the channel and with its radius of curvature increasing with the frequency until a frequency of about 3,000 cycles is reached when the wave front at each outlet is substantially planar. For frequencies between 3,000 cycles and 12,000 to 15,000 cycles the wave front remains substantially planar at each channel opening. For frequencies below as well as above 3,000 cycles the sound density at each outlet is substantially uniform over the outlet area.

In view of this analysis it will be apparent that the horn illustrated in the drawing will produce substantially the same sound distribution in space for all frequencies from the cut off frequency up to a frequency as high as 12,000 cycles as a true spherical wave front coincident with all channel outlets. For the lower frequencies the small departure from this true spherical wave front due to the fact that each channel gives a spherical wave front about a center lying on its own axis is negligible in its effect on the sound distribution in free space because the wave lengths for such frequencies are relatively large compared to the magnitude of said departure. The planar wave front from each channel for the frequencies above 3,000 cycles will also not depart from a true spherical wave front coincident with all channel outlets in an amount sufficient to cause any substantial non-uniformity in the sound distribution in the free space defined by the solid angle subtended by the horn outlets.

While the particular form of this invention described above has an equal number of channels in both directions it will be obvious that the invention is not limited to this construction. For example the horn may comprise channels in four rows with eight channels in each row to give a wider sound distribution say in a horizontal plane than in a vertical plane.

A mouth opening for each channel of a width of about seven inches has been found suitable when the highest frequency to be transmitted is in the neighborhood of 12,000 to 15,000 cycles. In general it may be stated that the higher the maximum frequency to be transmitted the smaller should be the diameter of the individual channel mouth opening. The maximum difference between a planar wave at the mouth of each channel and the spherical surface defined by the entire channel assembly should not be greater than half the wave length of the highest frequency to be transmitted, which relationship in effect is defining the mouth opening in terms of the wave length and the radius of curvature with respect to the point 40 of Fig. 1. Another viewpoint which must be considered in choosing d the diameter in centimeters of the individual mouth opening is as previously explained that d should not be greater than the value given by the expression

$$d=\frac{5.10^7}{f_{max}f_0},$$

where f_{max} is the highest frequency to be transmitted by the horn. Thus for a maximum frequency of 12,000 cycles and a cut off frequency of 200 cycles the mouth opening of each channel should not be greater than about 8 inches.

Since the particular horn structure described above does not constitute an efficient acoustic coupler between the loud-speaking receiver and the outer air for frequencies below 200 cycles it will generally be found advisable to supplement the horn structure of the present invention by another horn particularly designed to be efficient for the extremely low frequency range of speech or music.

While only one form of this invention has been disclosed in the drawing, it is to be understood that the invention is capable of widely different embodiments without departing in any wise from the spirit of this invention as defined in the appended claims.

What is claimed is:

1. In a sound producing device a plurality of exponentially tapered horns each having independent side walls, a common throat portion for the inlets of all of said horns, said horns having their outlets juxtaposed and arranged to present a combined mouth opening defining a substantially spherical surface segment, said horns having inlets of such areas that each inlet receives substantially the same volume of sound from an impressed sound wave having a planar wave front.

2. In a sound producing device a plurality of horns having their outlets joined with contacting edges to produce a substantially single mouth opening except for the edges of the intervening side walls of each horn, the mouths of said horns being so shaped that all of the mouths lie in a substantially spherical surface portion having a radius of curvature less than the length of each horn from inlet to outlet.

3. In a sound producing device a plurality of exponentially curved horns having independent side walls each horn being substantially rectangular in cross-section, the axes of said horns being of substantially equal length measured from inlet to outlet, said axes being angularly spaced with respect to each other as viewed from the horn outlets, said inlets being joined to a common throat portion having a cross-sectional area substantially equal to the combined cross-sectional area of said inlets, said outlets being joined together to present a substantially single mouth opening, the spaces between said horns lying between said inlets and outlets being filled with sound absorbing material.

4. In a sound producing device a plurality of exponentially curved horns compactly assembled at their inlets and outlets with no intervening gaps between adjacent outlets or between adjacent inlets, said inlets lying in a common plane, said outlets terminating in a substantially spherical surface segment, and a common throat portion for all said inlets.

5. In a sound producing device a plurality of exponentially curved horns of substantially rectangular cross-sectional area having inlets of substantially equal area and outlets of substantially equal area, said inlets being compactly assembled with all of said inlets terminating in a common plane, a common throat portion for said inlets, said outlets being connected together to give a substantially single mouth opening for said horns, the axes of said horns measured from inlet to outlet being substantially of equal length, said horns being so grouped that one of said horns is entirely surrounded by others of said horns when viewed from a direction at right angles to the axis of the surrounded horn.

6. In a sound producing device a plurality of horns of substantially equal length from inlet to outlet, a common throat portion for supplying sound energy to all of said inlets, said outlets being compactly arranged to present substantially a single mouth opening, said horns having individual side walls with spaces between adjacent horns, and a packing of sound absorbing material in the spaces between the side walls of adjacent horns to reduce the tendency of said side walls to vibrate.

7. In a sound producing device, a plurality of horns each having independent side walls, said horns having their outlets juxtaposed and arranged to present a combined mouth opening defining a substantially spherical surface segment, and means comprising a common loudspeaking receiver and a common throat portion for supplying sound waves which arrive at said inlets on a plane wave front to cause the sound density in each horn to be substantially the same value for each frequency over the frequency range to be transmitted by said device, said inlets having such areas that each inlet receives substantially the same volume of sound from said receiver.

8. In a sound producing device, a plurality of horns each having independent side walls, a common throat portion for supplying sound energy to the inlets of all of said horns, said horns having their outlets compactly arranged to present substantially a single mouth opening, said horns being arranged to provide spaces between adjacent horns intermediate their inlets and outlets and a packing of sound absorbing material in the spaces between the side walls of adjacent horns.

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