

June 20, 1944.

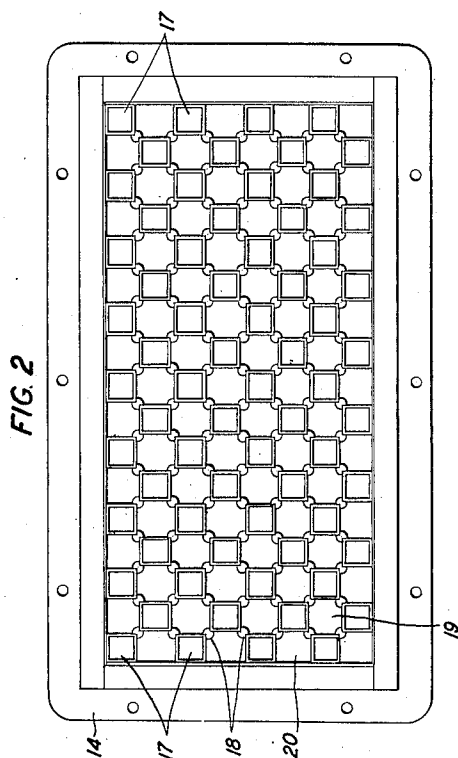
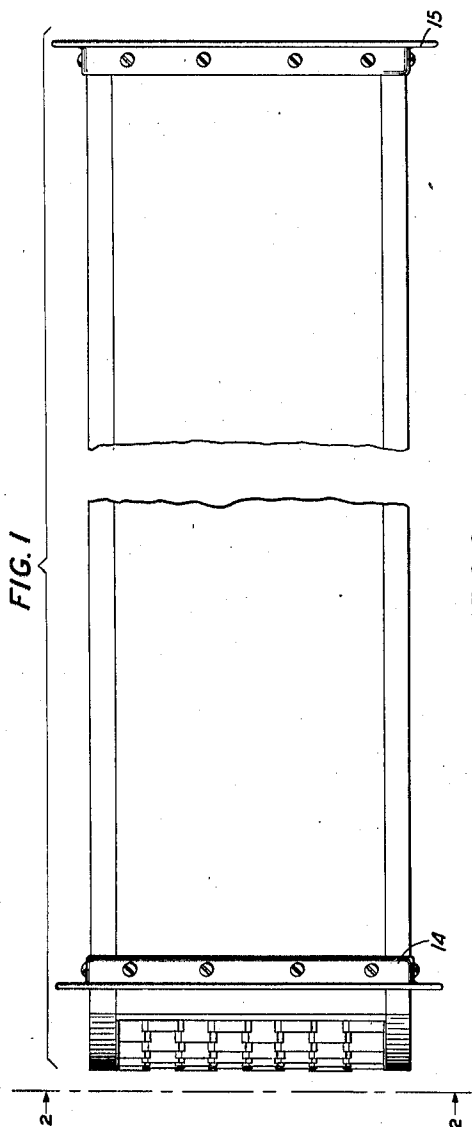
L. G. BOSTWICK ET AL

2,351,913

ACOUSTIC DELAY DEVICE

Filed Dec. 30, 1942

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

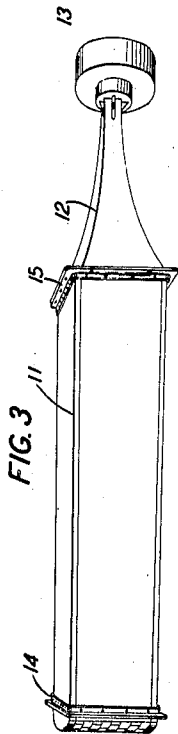
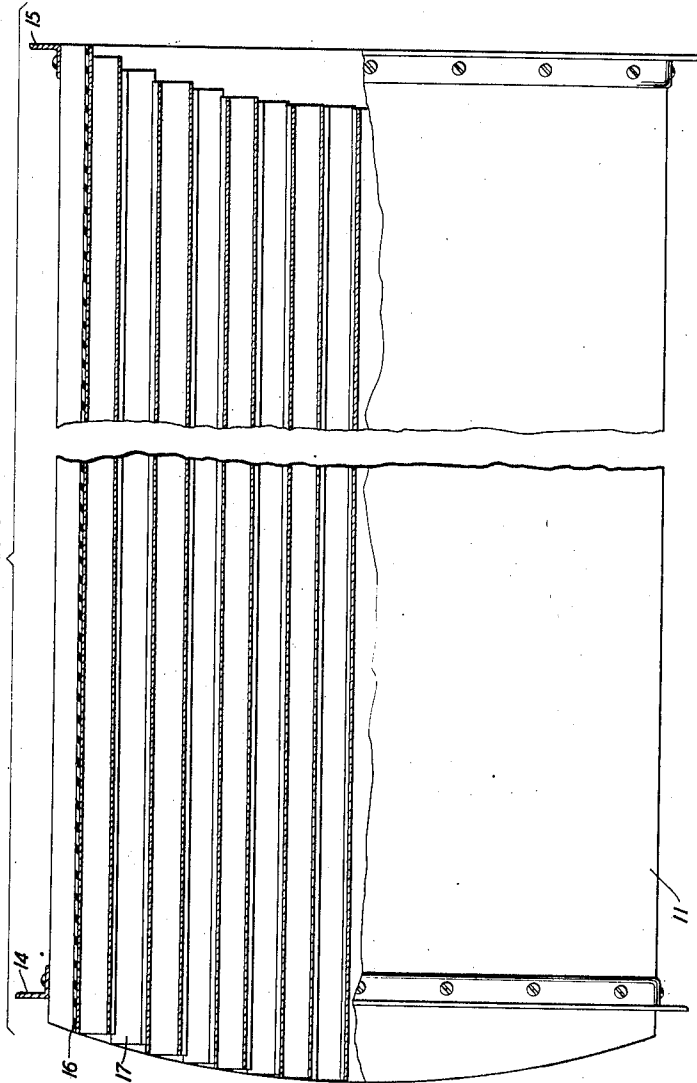


FIG. 3



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## UNITED STATES PATENT OFFICE

2,351,913

## ACOUSTIC DELAY DEVICE

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Application December 30, 1942, Serial No. 470,702

4 Claims. (Cl. 181—27)

This invention relates to acoustic delay devices and the object of the invention is to delay the projection of complex sound waves without material change in the energy distribution of the wave front or in the relative magnitudes of the various frequency components.

One important application for devices of this type is in high quality sound projection systems such as those commonly used in sound picture theaters. In such systems it is common practice to use separate loud-speakers for the high and low frequencies in order to obtain satisfactory response over a wide range of frequencies. From the standpoints of efficiency and proper sound distribution, horns are preferable to direct radiators but the use of separate high and low frequency horns of the usual types introduces phasing problems.

As is well known, the low frequency exponential horns of such systems are long whereas the high frequency horns are relatively short. When such horn combinations are disposed with their mouths in substantially the same plane behind a picture screen, for example, the difference in the lengths of the air paths in the low and high frequency units results in phase differences which noticeably impair the reproduction. It is impractical to remedy this by merely using a longer high frequency horn with a lower cut-off frequency or slower expansion rate since in that case the small throat section is long and the resulting sound pressure so high that the non-linear expansion characteristic of air when transmitting large amounts of sound energy introduces prohibitive distortion. If, on the other hand, the high frequency unit is moved back to equalize the air paths from the receiver units to the audience there is a widely separated double source of sounds in the frequency range where both the high and low frequency units are radiating and the frequency components in this range are not distributed properly over the listening area. In the case of sound picture theaters, this arrangement would have the further and more serious disadvantage that a considerable part of the high frequency energy would be reflected back by the rear surface of the screen causing objectionable back-stage reverberation.

According to this invention the projection of sound from the mouth of a horn is delayed to any extent desired by means of a sound conduit of the proper length which intercepts the wave emanating from the mouth of the horn and transmits it without substantial change so that, except for the time delay introduced, the wave

projected from the discharge end of the conduit is substantially the same as if the horn mouth were disposed in the plane of the discharge end of the conduit. The conduit is preferably of a uniform cross-sectional area equal to the area of the horn mouth and is subdivided longitudinally into a large number of cells or tubes having transverse dimensions which are preferably small as compared with the wave-length of the highest frequency to be transmitted. The segmental waves entering such cells or tubes will be transmitted without substantial change in wave front and on emerging from the discharge end of the conduit will recombine to reform the wave front existing at the horn mouth. Although the individual sound passages in this construction are small, the non-linear distortion is negligible because the sound energy is divided among many passages thereby keeping the sound pressure in each passage of low magnitude.

When such a conduit of a length approximating the difference in the lengths of the high and low frequency horns is used with the high frequency horn, the discharge end of the conduit is placed substantially in the plane of the mouth of the low frequency horn unit. The phase differences are thereby eliminated and the two horns function as a single sound source as illustrated in our copending application Serial No. 470,703, filed December 30, 1942.

The invention will be more clearly understood from the following detailed description and the accompanying drawings in which:

Fig. 1 is a side view of a delay conduit according to the invention;

Fig. 2 is an end view of the discharge end of the conduit;

Fig. 3 shows the conduit attached to a high frequency horn type loud-speaker; and

Fig. 4 is a side view of the conduit partially in section to show the arrangement of the cells or tubes.

Referring to the drawings, the conduit 11 shown for purposes of illustration is rectangular in cross section and of the proper dimensions to fit the rectangular mouth of the exponential horn 12 (Fig. 3) which has a driving receiver unit 13. The conduit may be constructed of plywood with stiffening and mounting flanges 14, 15 at the ends and with a suitable vibration absorbing lining 16 (Fig. 4) such as a thin sheet of soft gum rubber. The individual cells or tubes 17 may be of one inch square aluminum tubing with extruded rubber strips 18 of a cross section which is contoured to fit the corners of diagonally

adjacent tubes and hold them in their proper relative positions without metal-to-metal contact. Adjacent tubes or adjacent tubes and the walls of the conduit form other cells or tubes 19, 20 between the tubes 17 so that the whole cross-sectional area of the conduit is subdivided into a multiplicity of parallel acoustic paths each so small that the segmental wave fronts are not changed materially in their passage through the tubes.

The tubes 17 will ordinarily be of the same length and arranged at the inlet end of the conduit adjacent flange 15 on a concave arc, in one or both planes, so that the tube inlets are disposed on the circular front of the wave emanating from the associated horn as shown in Figs. 3 and 4. When the tubes are so arranged their other ends are disposed on a convex arc so that the segmental waves in recombining reform the wave front as it existed at the mouth of the horn and the sound is radiated from the conduit in the same manner as from the mouth of the horn when used alone but with a time delay proportional to the length of the conduit.

While it is desirable that when used in multiple horn combinations, such conduits should equalize the lengths of the air paths in the units, space considerations in some cases may require that the conduit be somewhat shorter. In general the phase differences are not particularly objectionable if the air paths are equalized to within one-half of the wave-length of the cross-over frequency at which the frequency band is divided between the high and low frequency horns.

The conduit is preferably straight as shown but in some applications particularly in theaters, where available space behind the screen is limited, the horn or the conduit or both may be curved to fit the unit into the space available. While the passages of the conduit shown are of equal length, it may be desirable in cases where a particular non-uniform field distribution of high frequency energy is required to obtain this by using a conduit having passages of different

lengths in order to obtain the necessary differences in phase between the sounds emerging from the several passages.

What is claimed is:

5 1. An acoustic conduit of uniform cross section having walls subdividing it into a plurality of passages of equal length with the ends of the passages disposed on the curved front of an acoustic wave to be transmitted through the conduit, the cross-sectional dimensions of the passages being small as compared with the wave-length of the highest frequency to be transmitted so that the sound entering the passages is transmitted without distortion and on emerging 15 from the conduit reforms substantially the wave front of the sound entering the passages.

2. An acoustic conduit comprising bounding walls and a plurality of tubes of uniform cross-section throughout their lengths within the conduit and held therein in spaced relation by longitudinal strips of resilient material to form other sound passages between the outer walls of the tubes.

3. A conduit according to claim 2 in which the tubes are of equal lengths with their ends disposed on a curve simulating the curved wave front of a sound wave and in which the cross-section of each tube is so small that the curvature of the wave front is not materially changed by the passage of a sound wave through the conduit.

4. In combination a horn and means for delaying the radiation of sound waves from the horn without substantially modifying the wave front at the mouth of the horn comprising an acoustic conduit of a uniform cross-sectional area equal to the area of the mouth opening of the horn attached to the mouth opening and being divided longitudinally into a multiplicity of acoustically separate paths each of a cross-sectional area small as compared with the wave-lengths of the frequencies transmitted by the horn.

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