

Dec. 3, 1929.

V. A. SCHLENKER

1,738,322

ACOUSTIC DEVICE

Filed Aug. 17, 1927

2 Sheets-Sheet 1

FIG. 1.

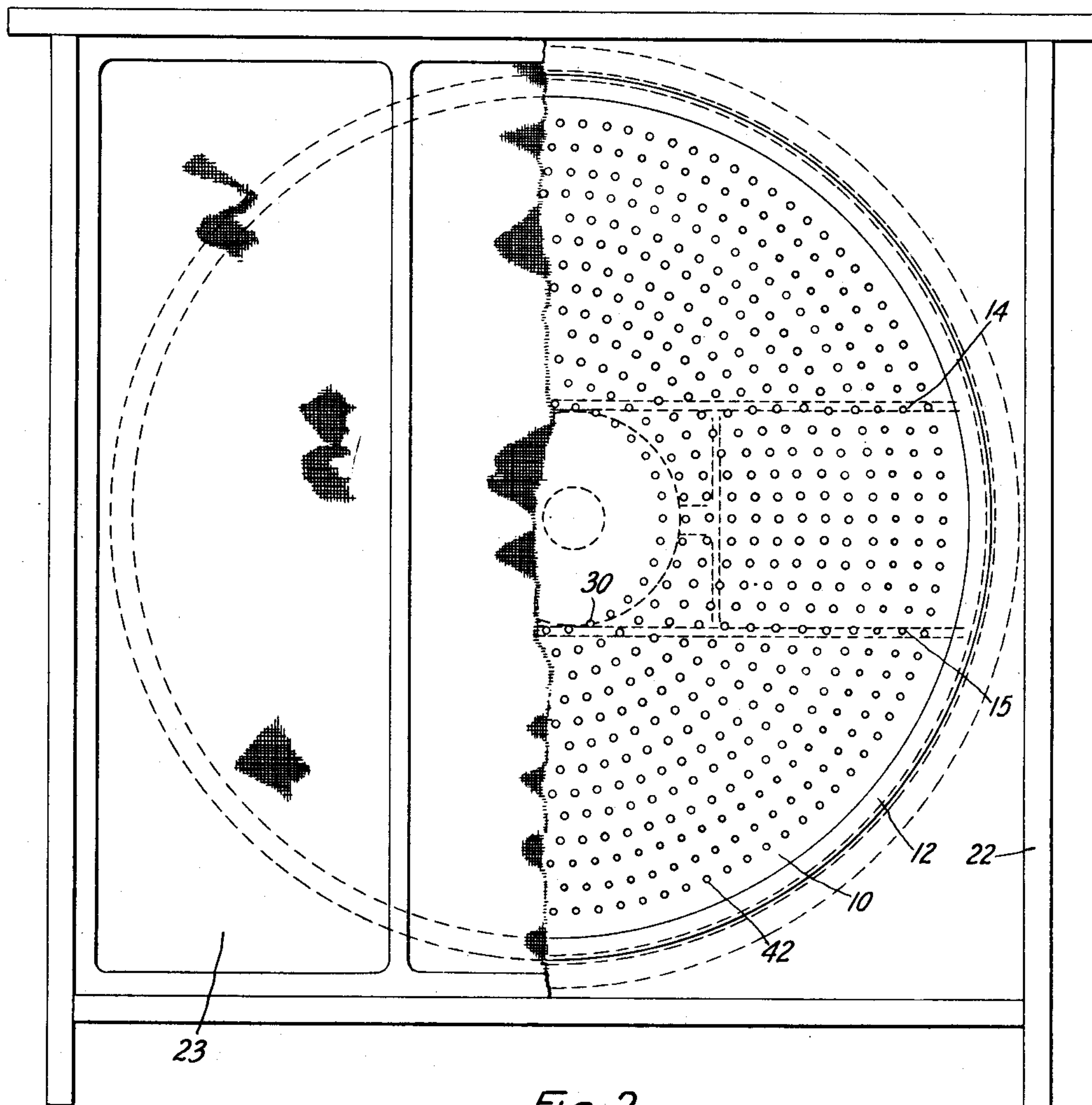
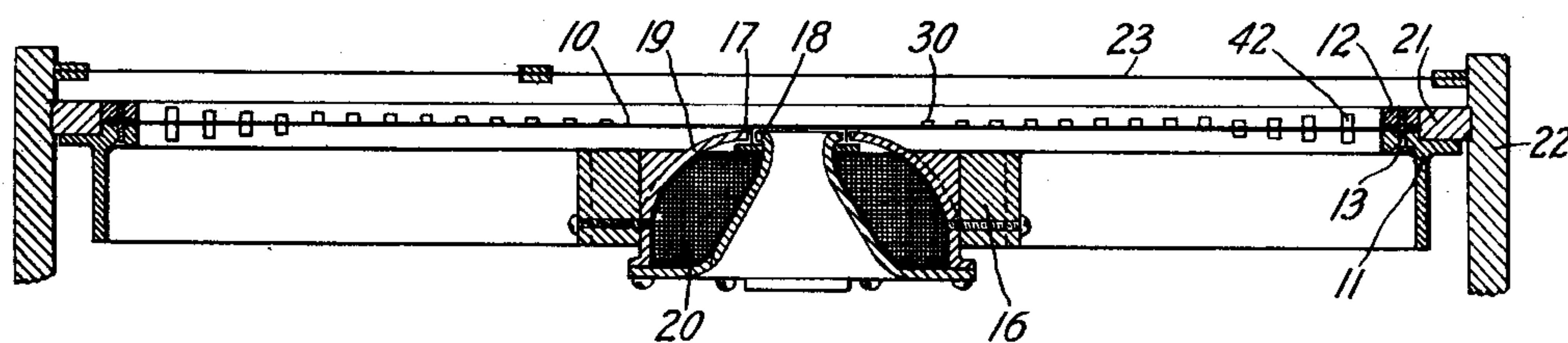


FIG. 2.



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FIG. 3.

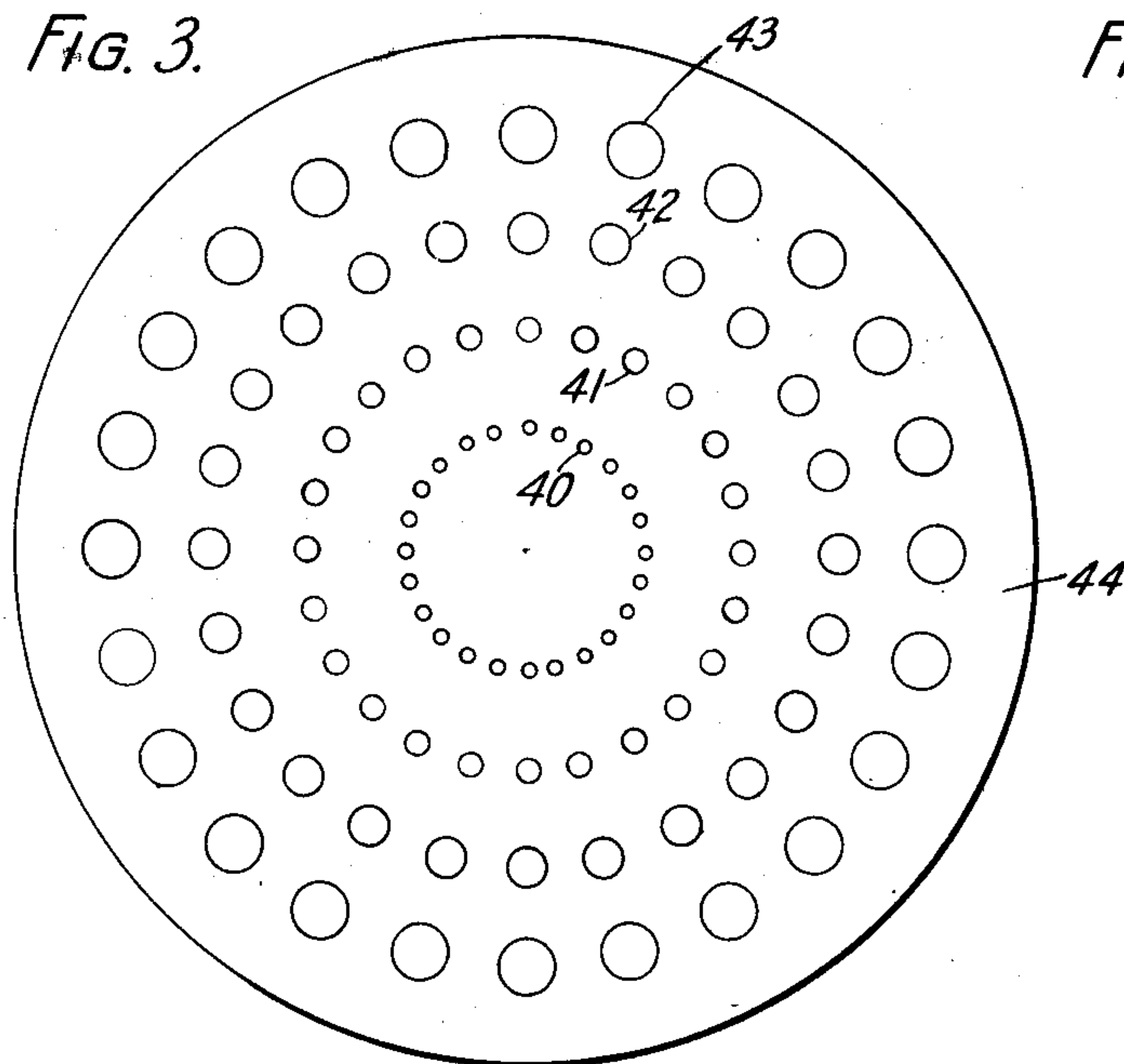


FIG. 4.

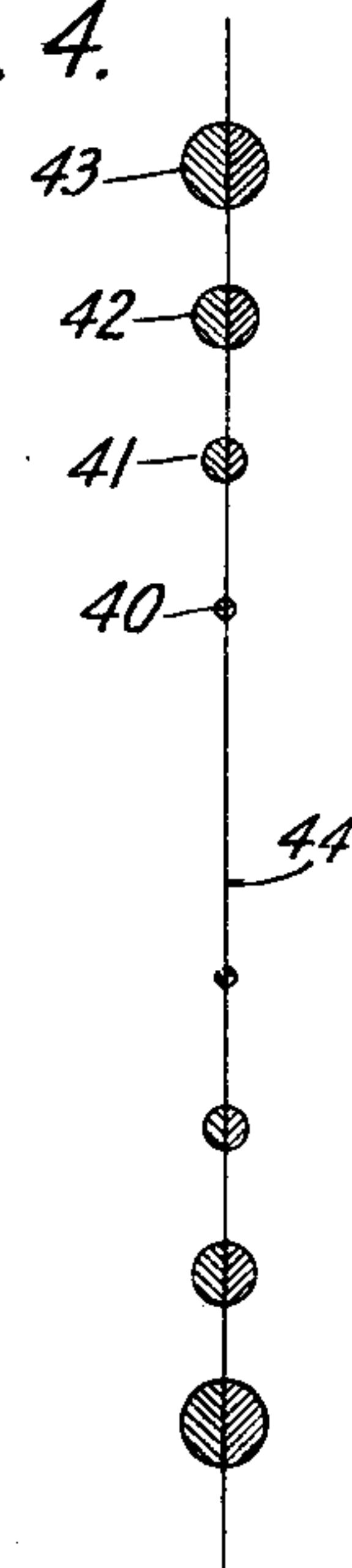


FIG. 5.

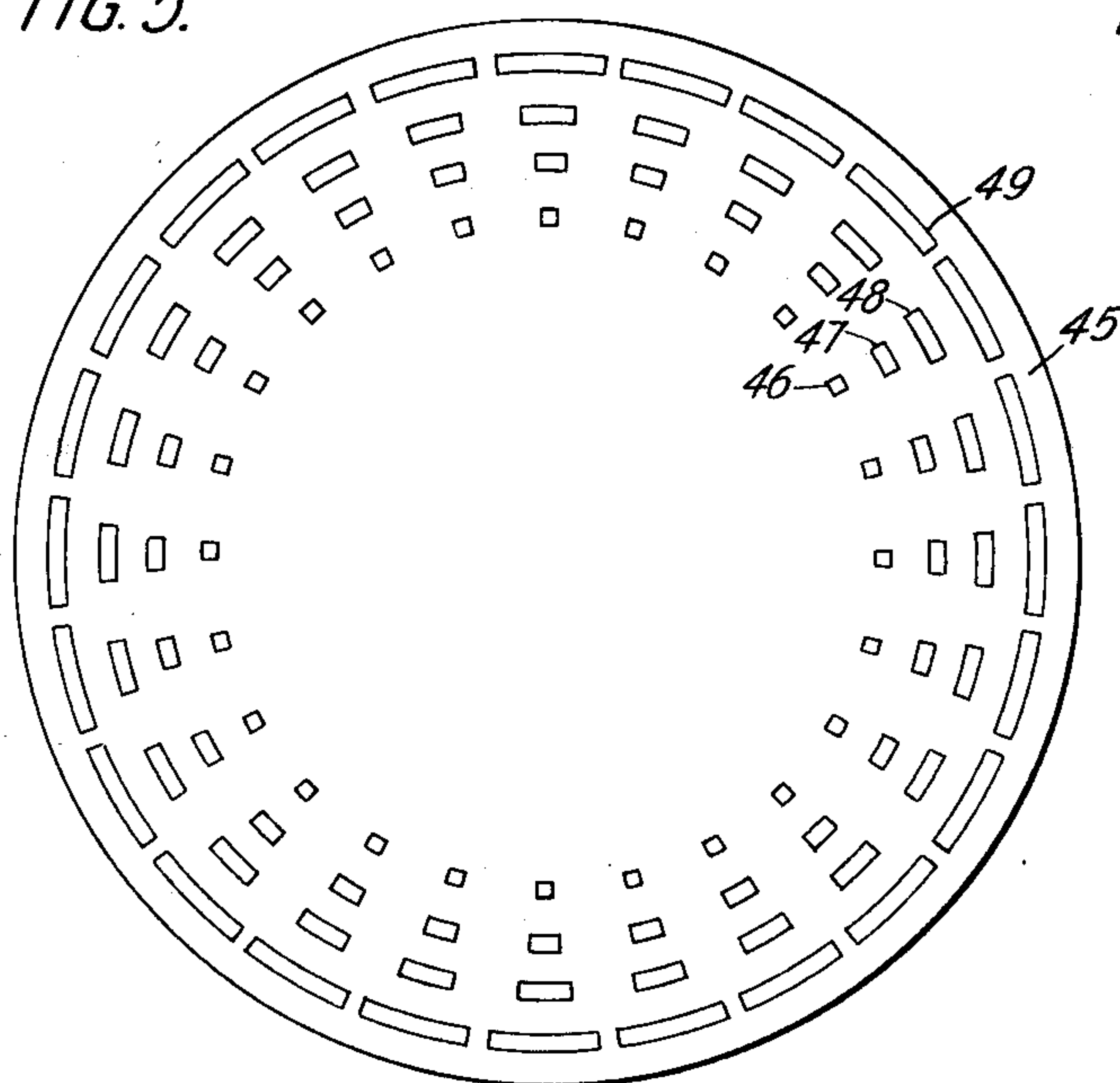
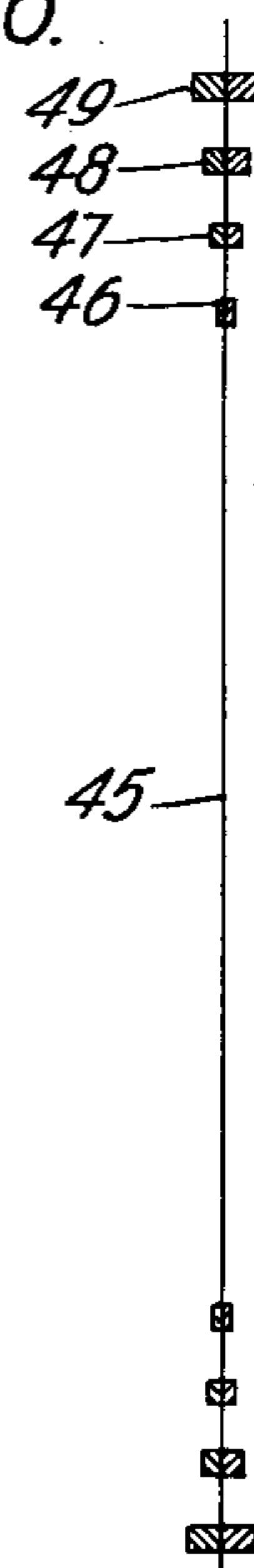


FIG. 6.



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ACOUSTIC DEVICE

Application filed August 17, 1927. Serial No. 213,462.

This invention relates to sound radiators and more particularly to radiators of the direct acting type.

With the usual type of sound radiating surfaces having a uniform thickness throughout their diameters it is difficult to impart vibrations of all frequencies to the air to produce corresponding sound vibrations. This is due to the fact that the surface at various distances from the center presents increasingly high impedances to the frequency vibrations propagating outward as a wave motion from the driving element. These high impedances attenuate the energy transmitted and limit the range of frequencies that can be reproduced as air vibrations. Furthermore, reflection at the boundary of the surface introduces irregularities in the vibrations transmitted to the air. When these difficulties are overcome by forming the radiating surface so that it has a tapered cross-section from the center to the periphery, the low frequency energy is dissipated in the comparatively rigid thick section of the radiator and is not transmitted to the air.

An object of this invention is to prevent stiffness in a loaded sound radiator so that all frequencies within the audible range may be radiated efficiently.

In accordance with one embodiment of the invention, the vibratile member or diaphragm comprises, a relatively thin sheet of metallic material of uniform thickness, which is preferably stretched and clamped in a metal member which maintains it under a high tension uniformly in all directions. A driving element of the electrodynamic type is secured to the diaphragm at a position slightly off-center, to transmit frequency vibrations thereto. Fixed to the large plane surface of the diaphragm are equally distributed lumped masses of loading, preferably tapering in density from the periphery to the center. In effect, the single vibratile member comprises a plurality of individual diaphragms driven by a common element, each efficiently radiating a definite band of frequencies within the range of speech and music. This arrangement provides a sound radiator in which the forced vibrations of any

frequency are confined to an area the linear dimensions of which vary inversely, as the frequency, and the problem of matching the impedances over the frequency range is greatly simplified. In effect, the structure may be regarded as a tapered low-pass mechanical filter, the successive varying masses of impedance on each diameter corresponding to the series inductance of the electric filter and the connecting thin portions of the diaphragm corresponding to the shunt capacities. By limiting the surface areas of the masses and spacing these masses equidistant in both directions the tendency toward stiffness is avoided, thereby facilitating the radiation of very low frequencies. Furthermore, the density of the masses are so proportioned that the mass reactances of the air are neutralized throughout the system from the driving element of the air and the resistances are matched.

A large variety of such structures is possible with this invention, depending upon how the mass, stiffness and radial length of section are made to vary with the radius. Furthermore, the invention is not limited to a stretched plane diaphragm but may be employed with other types of diaphragms well known in the art.

A more detailed description of the invention follows and is illustrated in the accompanying drawings.

Fig. 1 is a view of a sound radiator enclosed in a chamber with a portion of the covering cut away to show the detailed construction.

Fig. 2 is a cross-sectional view of Fig. 1 showing the arrangement of the driving unit with respect to the stretched diaphragm and the arrangement of the loading masses.

Figs. 3 and 4 show a modified form of the invention in which the loading is applied to the surface in the form of spherical masses.

Figs. 5 and 6 show another modification of the invention in which segmented rings are employed for distributing the loading over the surface of the diaphragm.

Referring particularly to Fig. 1 and Fig. 2 of the drawing, the vibratile member or diaphragm 10 may in one embodiment of the in-

vention comprise a metallic alloy composed of approximately 98½% aluminum and 1½% manganese, which is rolled down to a thickness less than 0.005 inch and preferably 0.001 inch or 0.002 inch. Among the desired properties for a diaphragm material are low mass and high tensile strength such that the diaphragm may be stretched, without going beyond its elastic limit, to give it such a degree of stiffness that the velocity of transverse vibrations therein is at least one-fourth of and preferably equal to the velocity of sound in air. Other materials having properties similar to those possessed by this material may be used as a vibrating member. The diaphragm 10 is maintained under high tension uniformly in all directions by a supporting frame 11 and a clamping ring 12 which is secured to the frame by the screws 13. A pair of parallel supporting members 14 and 15 extend across the frame member and are preferably formed integral with the frame as a casting. The diaphragm 10 is driven by an electrodynamic unit 16 which is supported by the cross-members 14 and 15 on the frame. The coil 17 of the electrodynamic unit is secured to the diaphragm so as to drive it along a circular line and is positioned between the annular pole faces 18 and 19 of the magnetic structure 16. The polarizing winding 20 is positioned within and substantially fills the hollow magnetic structure.

In accordance with this invention a relatively thin stretched diaphragm such as heretofore described may be improved by loading the diaphragm and preferably having the loading tapering in density over the surface thereof. The loading is preferably lumped to prevent undesirable stiffness in the diaphragm surface. The density of the loading is so proportioned with respect to the radius of the diaphragm that the linear dimensions of the masses of loading varies inversely as the frequency and results in each radius of loading acting as an individual diaphragm actuated by a common driving element. This arrangement produces definite areas of diaphragm surface in which each area efficiently radiates a particular frequency within the audible spectrum. In one arrangement of the invention the loading masses or impedances may be applied to the diaphragm surface in the form of brass weights 30 to 42 inclusive. These weights may be circular or square and are attached to the surface by any suitable means such as by cement or glue. The masses of loading are preferably equally distributed over the surface of the diaphragm 10 so that the distance between the masses are the same in both directions.

More specifically, the masses of loading may be either circular brass weights of .5 centimeter or square weights of .2 centimeter square and the desirable distance between

the masses in both directions may be 2 centimeters. The surface density of the masses is represented by

$$p=2.5 \times 10^{-4} r^2$$

where

p =grams per square centimeter and
 r =centimeters.

In one embodiment of a loaded vibrating member constructed in accordance with this invention the masses are distributed in the following manner, in which the data is given for a single series of weights on one-half the diameter of the surface of 35 centimeter radius. This includes the positions of the loading masses on the radii, the weight of the masses, and the height thereof

radius in centimeters—10—12—14—16—18—20—22—24—26—28—30—32—34

weight in grams—.1g.—.14g.—.20g.—.26g.—.32g.—.40g.—.48g.—.58g.—.67g.—.78g.—.90g.—1.02g.—1.15g.

height in centimeters—.06—.08—.12—.15—.19—.24—.28—.34—.39—.46—.53—.59—.68.

The masses on each circle are spaced at a distance of 2 centimeters and have the same weight and height. It will be seen from Fig. 2 that the masses of loading on the outer boundaries of the surface are distributed on both sides of the diaphragm in order to prevent any torsional strain in the surface due to the boundary masses projecting too much above the diaphragm surface.

The coil 17 of the driving element 16 is attached to the diaphragm so that its axis is offset from the center of the diaphragm 10 approximately two-tenths of the diameter of inner radius of loading masses. This is designed to prevent any vibrational waves reflected by the inner radius of loading masses from coming to a focus at the axis of the driving unit.

The vibrating surface 10, loaded in accordance with this invention with equally distributed masses 30 to 42 inclusive, in which the masses on successive radii from the center increase in magnitude, is so designed that the driving element 16 is for each frequency coupled to a diaphragm which is automatically resonant at that frequency, and the masses of loading on each radius produce an effect similar to the cut-off characteristic of the electrical filter. This cut-off characteristic may be called the critical radius for the frequency so that the vibration of the frequency is confined to an area, the linear dimensions of which vary inversely as the frequency. The impedance of the masses is made low enough compared with that of air so that the major part of the energy of the frequency has been radiated by the time the disturbance reaches the critical radius for that frequency. This effectively prevents reflection losses in the diaphragm surface.

Furthermore, substantially the entire output of the driving element is converted into sound vibrations. The equal distribution of the loading masses over the surface produces a vibrating member in which stiffness of the surface is avoided. Reducing the stiffness makes the critical radius for a given frequency smaller and facilitates radiation at very low frequencies.

The acoustic device of this invention has other characteristics similar to the electrical filter in that the masses of loading are comparable to the series inductance of the electrical filter and the thin surfaces of the diaphragm are comparable to the shunt capacities. Therefore, in effect, the loaded diaphragm constitutes a low-pass mechanical filter in which the cut-off frequency characteristic is relatively low, and the impedance is low enough compared with that of air, that substantially no reflection takes place at the loaded radii.

It has been found that the effectiveness of the air adjacent to the diaphragm surface to lower the cut-off point of the frequency characteristic of a highly tensioned diaphragm of the kind herein disclosed may be substantially increased by partially confining the air in proximity to the diaphragm. This may be accomplished by placing the diaphragm in a chamber or container so that the walls of the container project forwardly or backwardly, or both, from the plane of the diaphragm a short distance. This is shown in Figs. 1 and 2, in which the diaphragm 10 is attached to a baffle or partition 21, which is placed in a cabinet 22. Protective screens 23 which may comprise a silk covering mounted on a suitable frame are positioned in the openings in the front and back of the cabinet 22.

In accordance with this invention the masses of loading applied to the diaphragm surface may be designed and disposed on the surface of the diaphragm to meet individual requirements. For instance, as shown in Figs. 3 and 4, the loading masses 40 to 43 inclusive, are spherical in cross-section and are preferably attached on both sides of the diaphragm 44, the inner radius of loading masses being of low density and the masses 43 on the outer boundary of the diaphragm being of greater density. Similarly, in Fig. 5 the loading is applied to a circular diaphragm 45 in the form of circular segmented rings 46 to 49 inclusive, the inner masses 46 being of small density and widely spaced apart, while the boundary masses 49 are of great density and close together. If preferred, the segmented rings may be applied to both surfaces of the diaphragm 45, as shown in Fig. 6. The invention is not limited to the application of loading, particularly tapered loading, to stretched surfaces,

but may be applied to any desired material which functions as a sound radiator.

What is claimed is:

1. An acoustic device comprising a diaphragm having tapered lumped loading applied thereto. 70

2. A sound radiator comprising a vibrating member, a driving element therefor, and distributed loading masses affixed to said member, said masses being equi-distant from each other and varying in density toward the outer edge of said member. 75

3. A sound radiator comprising a vibratile member, a driving element therefor, and tapered lumped impedances distributed on the surface of said member, said impedances and member constituting elements of a low-pass mechanical filter. 80

4. A sound radiator comprising a vibratile member, a driving element therefor, tapered lumped impedances distributed on the surface of said member, and means for mounting said member so that it has substantially constant stiffness throughout its surface. 85

5. A sound radiator comprising a vibrating member, a driving element therefor, and mass impedances radiating from the center of said member, said masses having a surface area of approximately 2 centimeters and spaced from adjacent masses by approximately the same area, each radius of masses having like density and each mass of the series having varying density. 90 95

6. A sound radiator comprising a vibrating member, a driving element therefor, and distributed mechanical impedances affixed to said member, said impedances being so proportioned that substantially the entire output of said driving element is converted into air vibrations. 100 105

7. A sound radiator comprising a vibrating member, a driving element therefor, and distributed impedance masses associated with said member, said masses being so proportioned that the stiffness of said member is maintained substantially constant. 110

8. A sound radiator comprising a stretched vibrating member, a driving element therefor, and mechanical lumped loading applied to said member, whereby said driving element is effectively coupled to a plurality of diaphragms, each effectively radiating a particular band of frequencies. 115

9. A sound radiator comprising a vibrating member, a driving element therefor, and tapered lumped impedances distributed on successive diameters of said member. 120

10. A sound radiator comprising a vibrating member, a driving element therefor, and tapered impedances affixed to said diaphragm in concentric circles, the impedances of the inner circle of smaller value than the impedances of the outer circle, being complementary to the higher frequencies and the boundary 125 130

impedances being complementary to the lower frequencies.

11. An acoustic device comprising a diaphragm having lumped loading applied thereto, and means for mounting said diaphragm so that it has substantially constant stiffness throughout its surface.

12. An acoustic device comprising a plane diaphragm stretched substantially uniformly in all directions, and having tapered lumped loading applied thereto.

13. An acoustic device comprising a stretched diaphragm, and means secured thereto for increasing its mass, the stiffness of said diaphragm being maintained constant.

14. An acoustic device comprising a stretched diaphragm of light material supported at its periphery, means secured near the central portion of said diaphragm for driving said diaphragm, and loading means secured thereto intermediate the central portion and the peripheral portion.

15. An acoustic device comprising a stretched diaphragm supported at its periphery and driven near its central portion, and a plurality of mass elements secured to said diaphragm, each of said elements occupying a small surface area on said diaphragm and increasing in magnitude from the central portion to the peripheral portion of the diaphragm.

In witness whereof, I hereunto subscribe my name this 13th day of August A. D., 1927.

VESPER A. SCHLENKER.