

July 30, 1946.

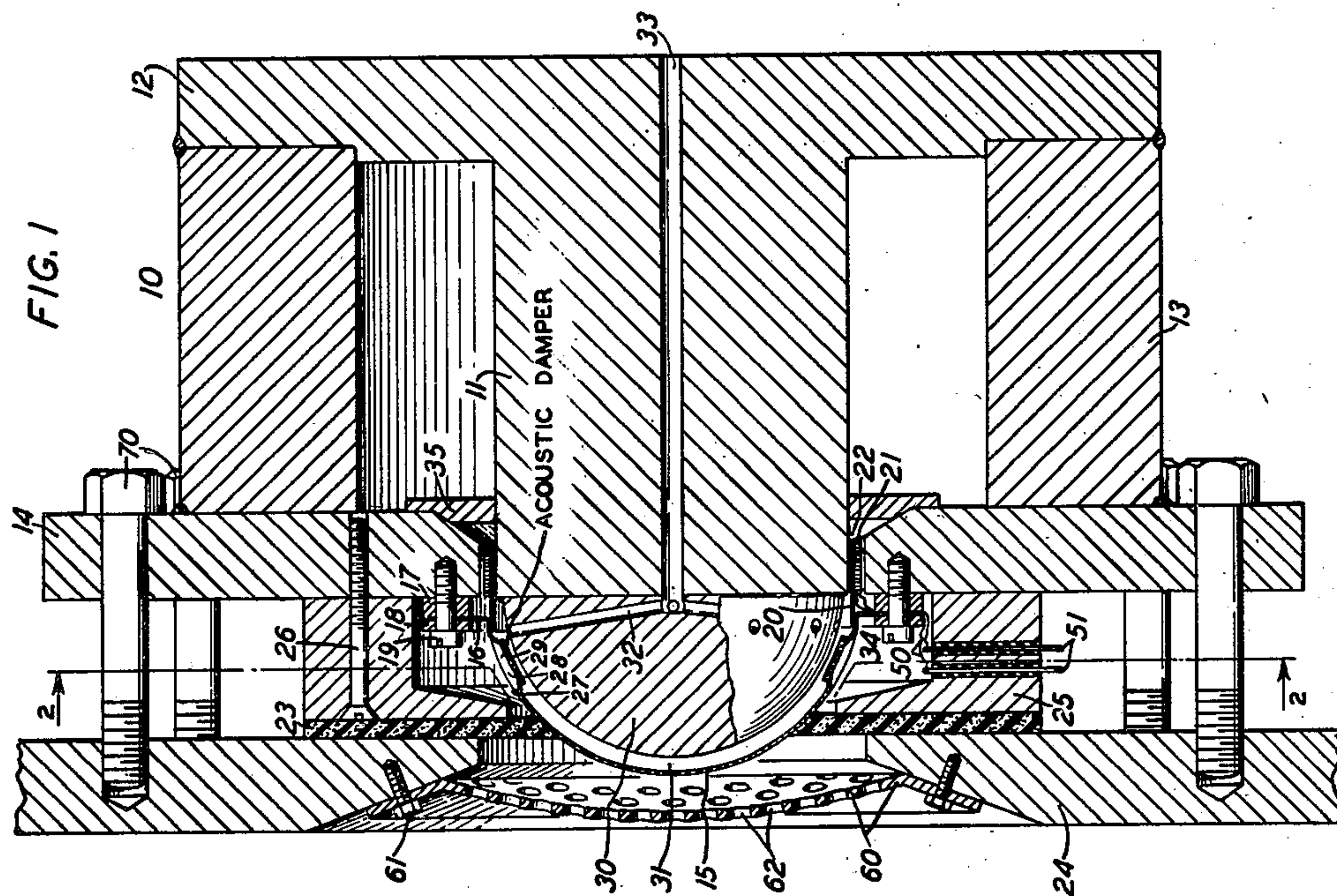
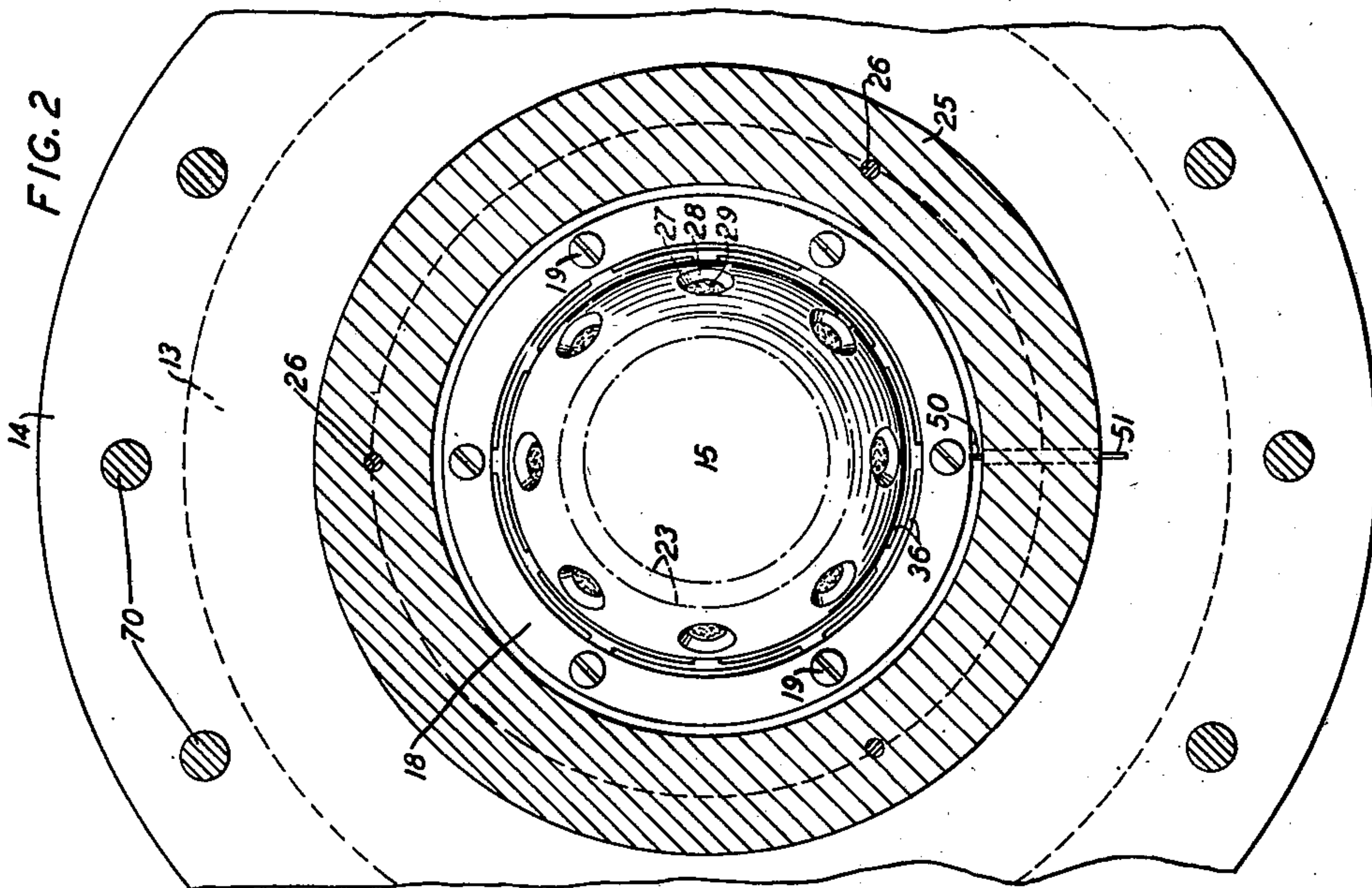
L. G. BOSTWICK

2,404,784

ACOUSTIC DEVICE

Filed June 7, 1940

3 Sheets-Sheet 1



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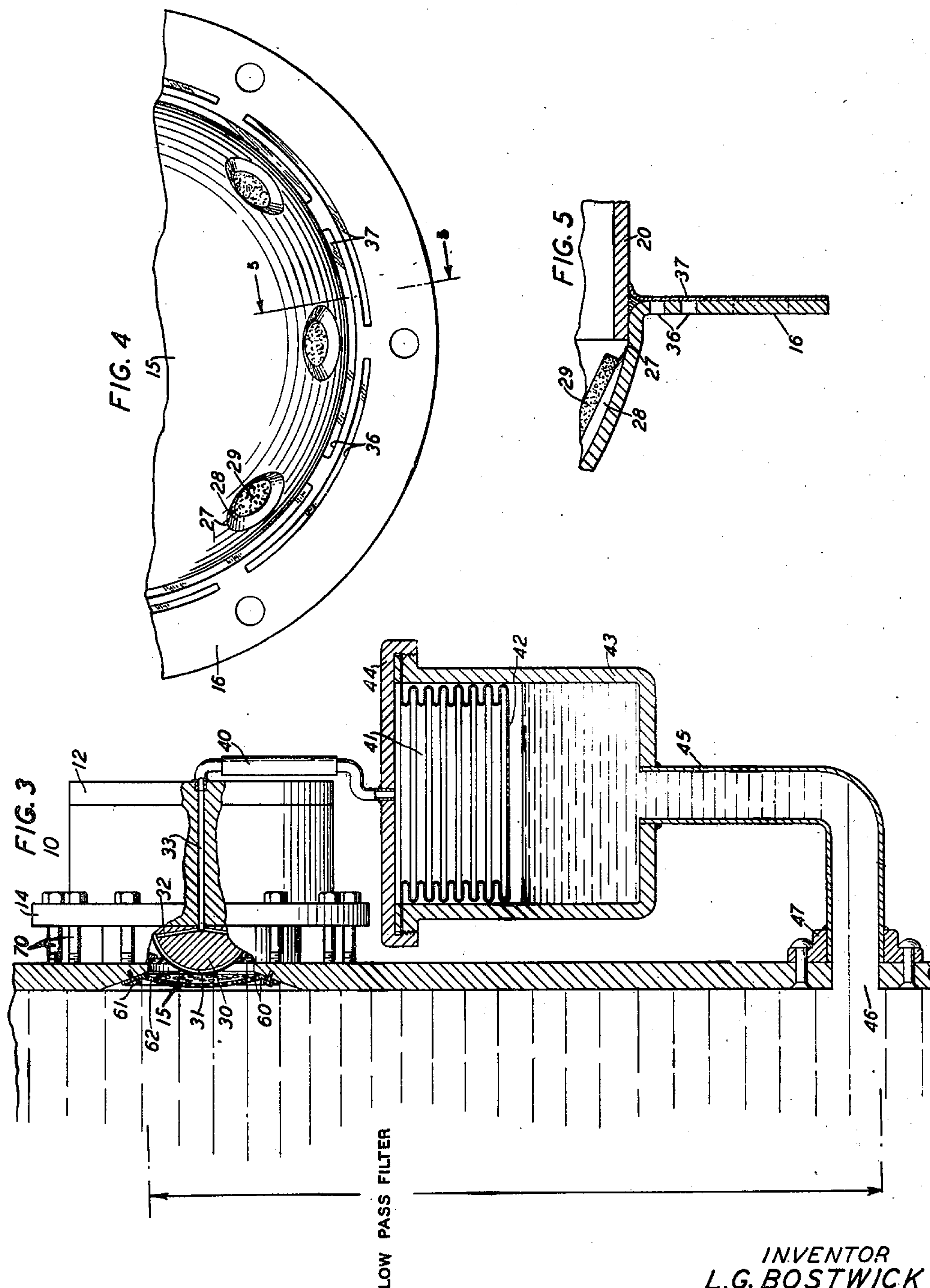
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FIG. 10

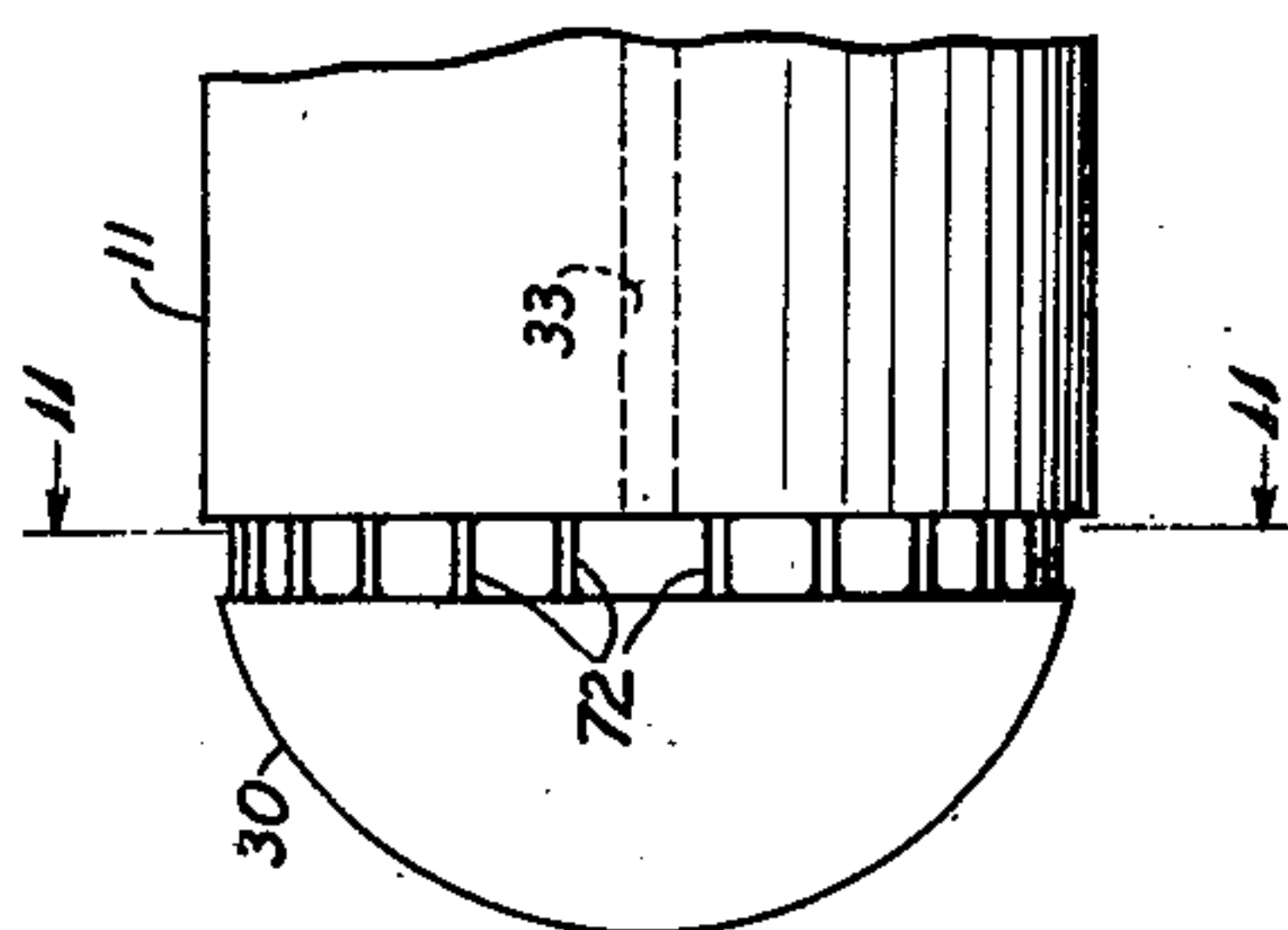


FIG. 11

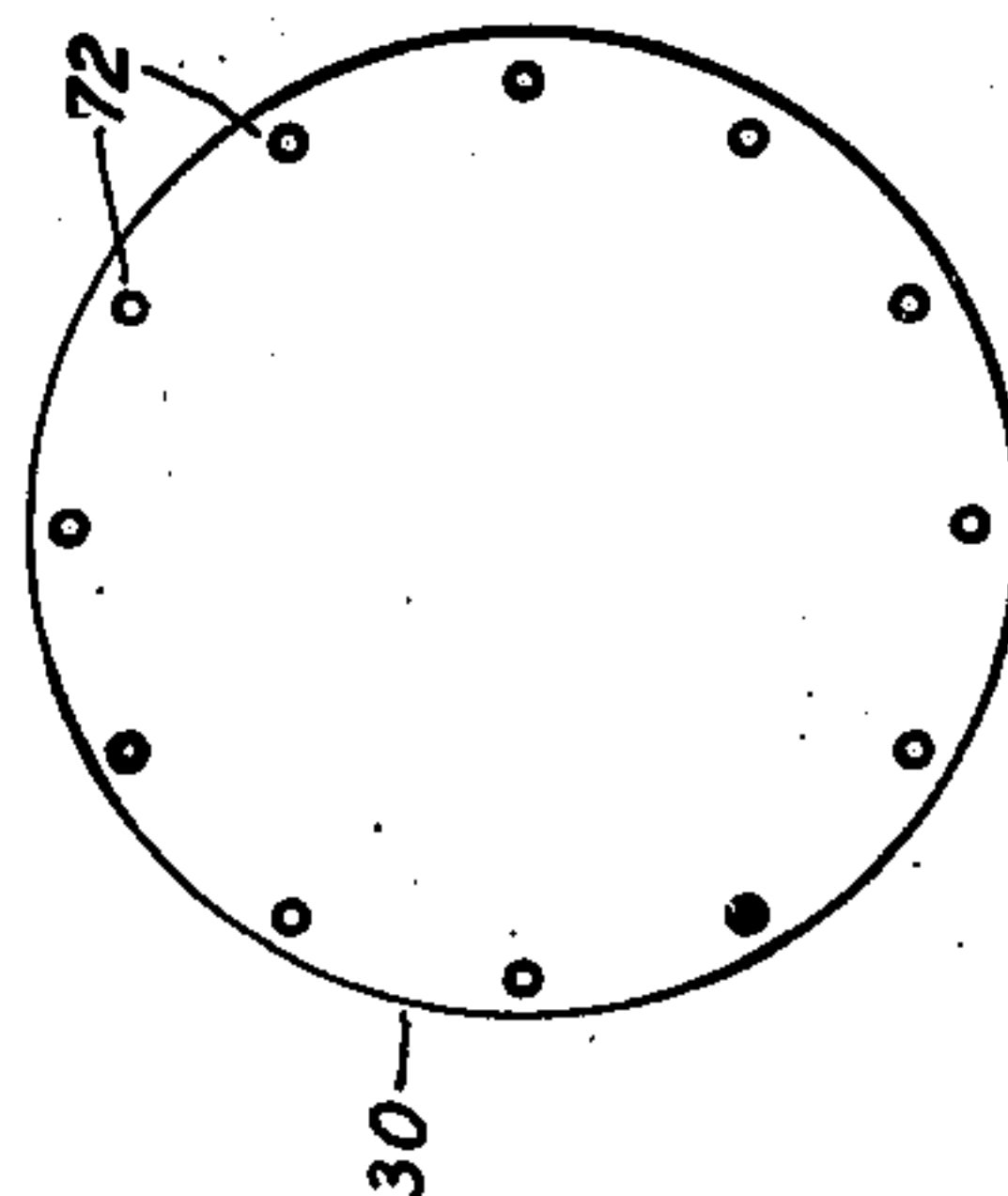


FIG. 8

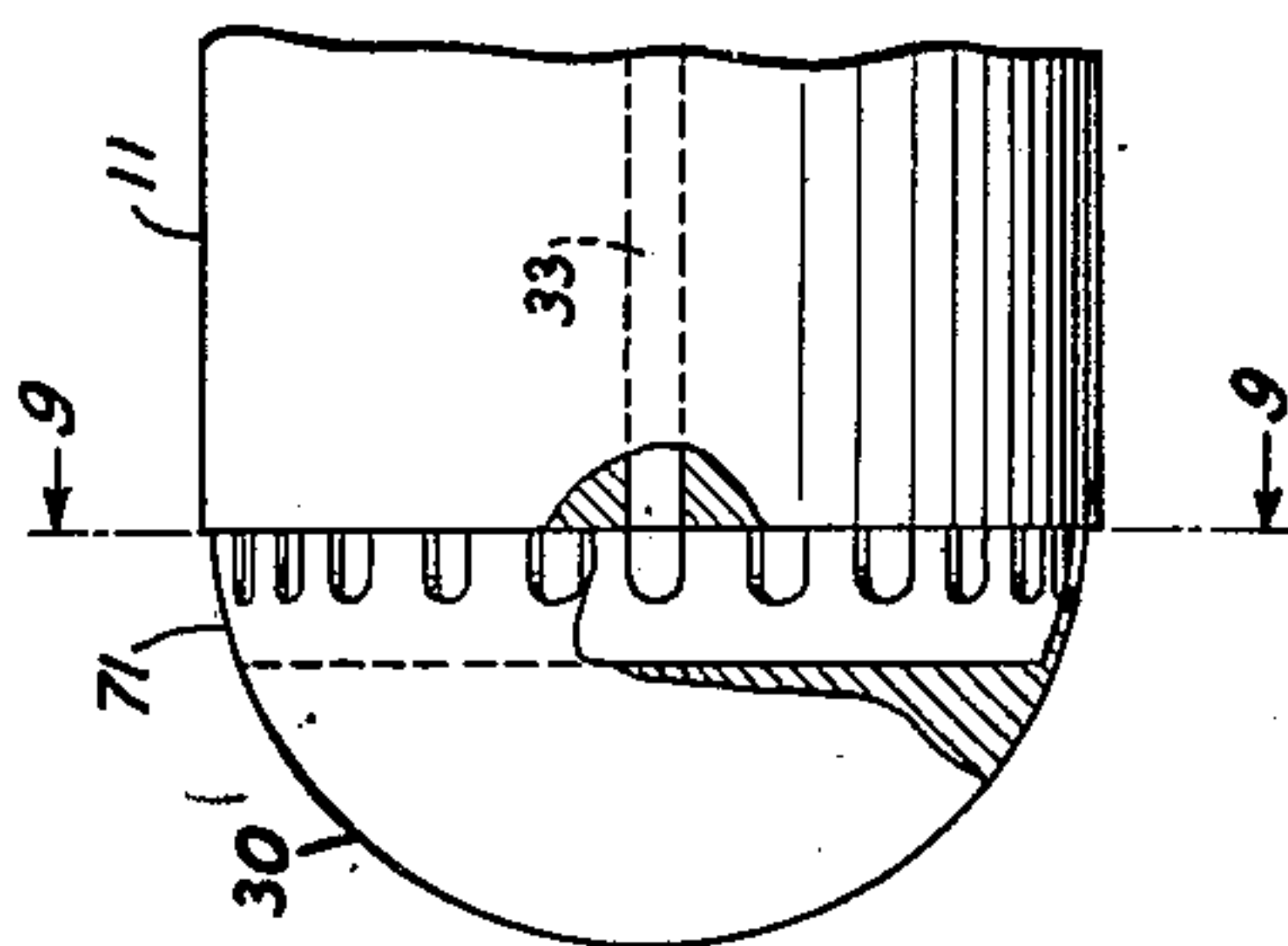


FIG. 9

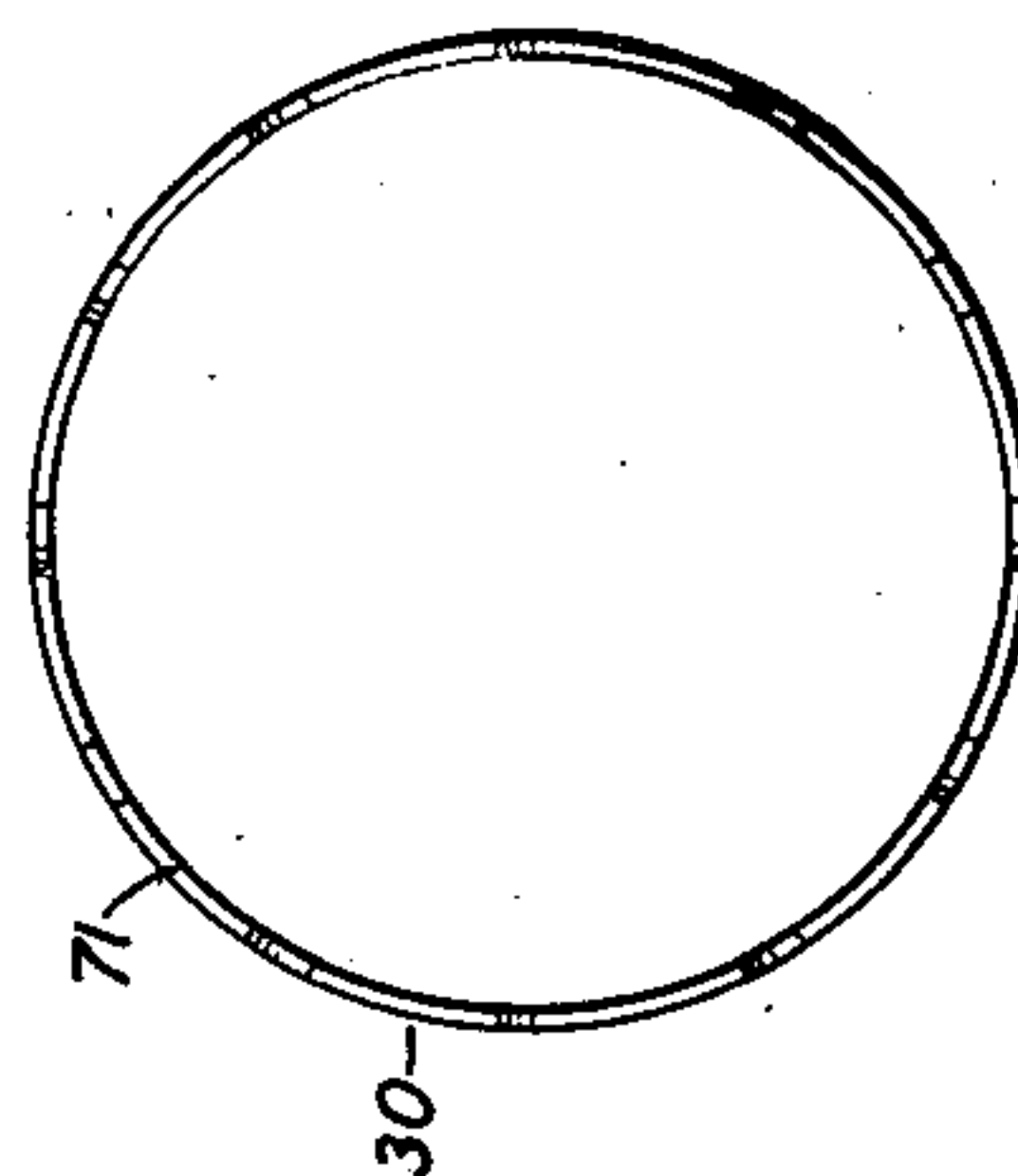


FIG. 6

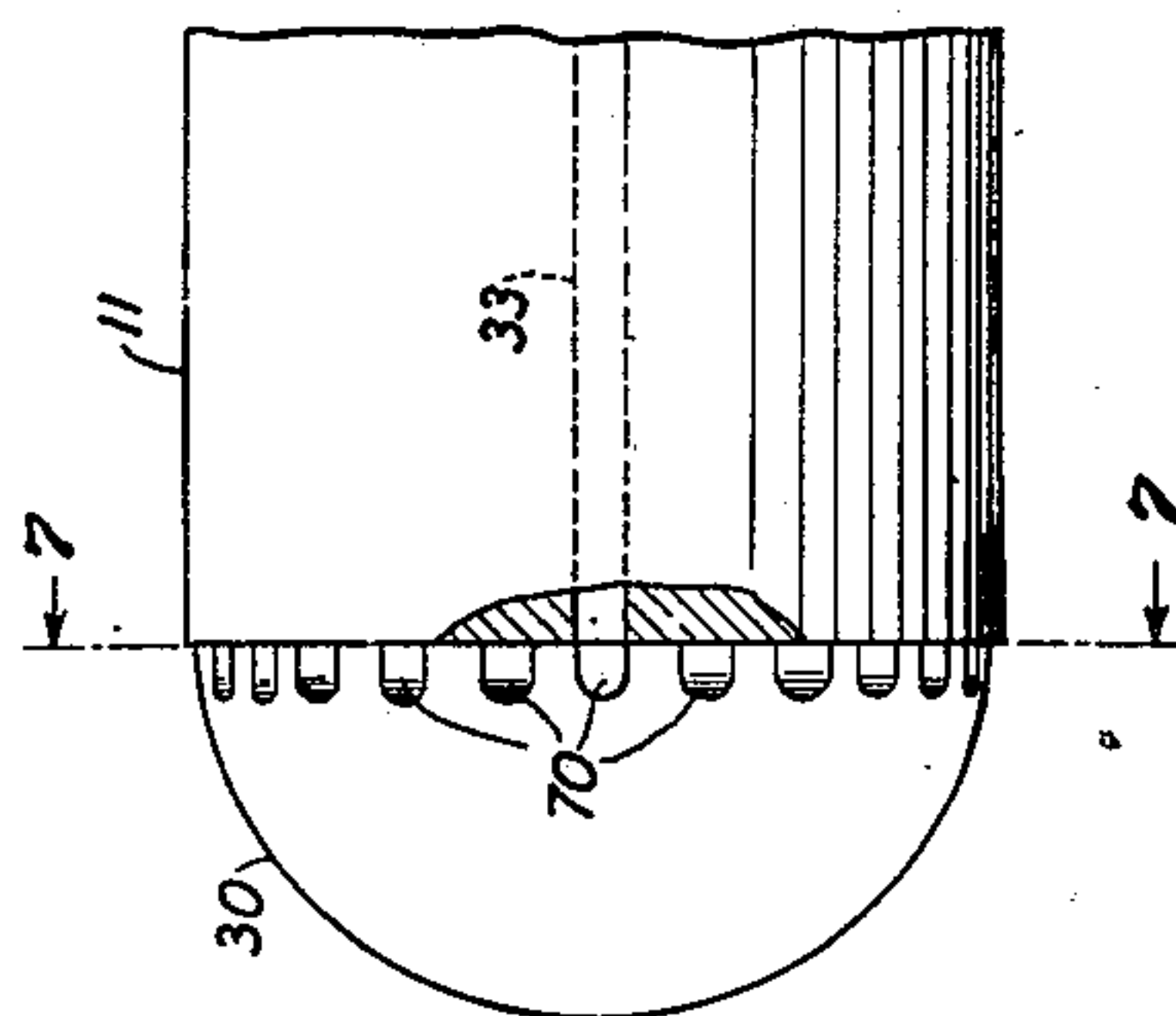
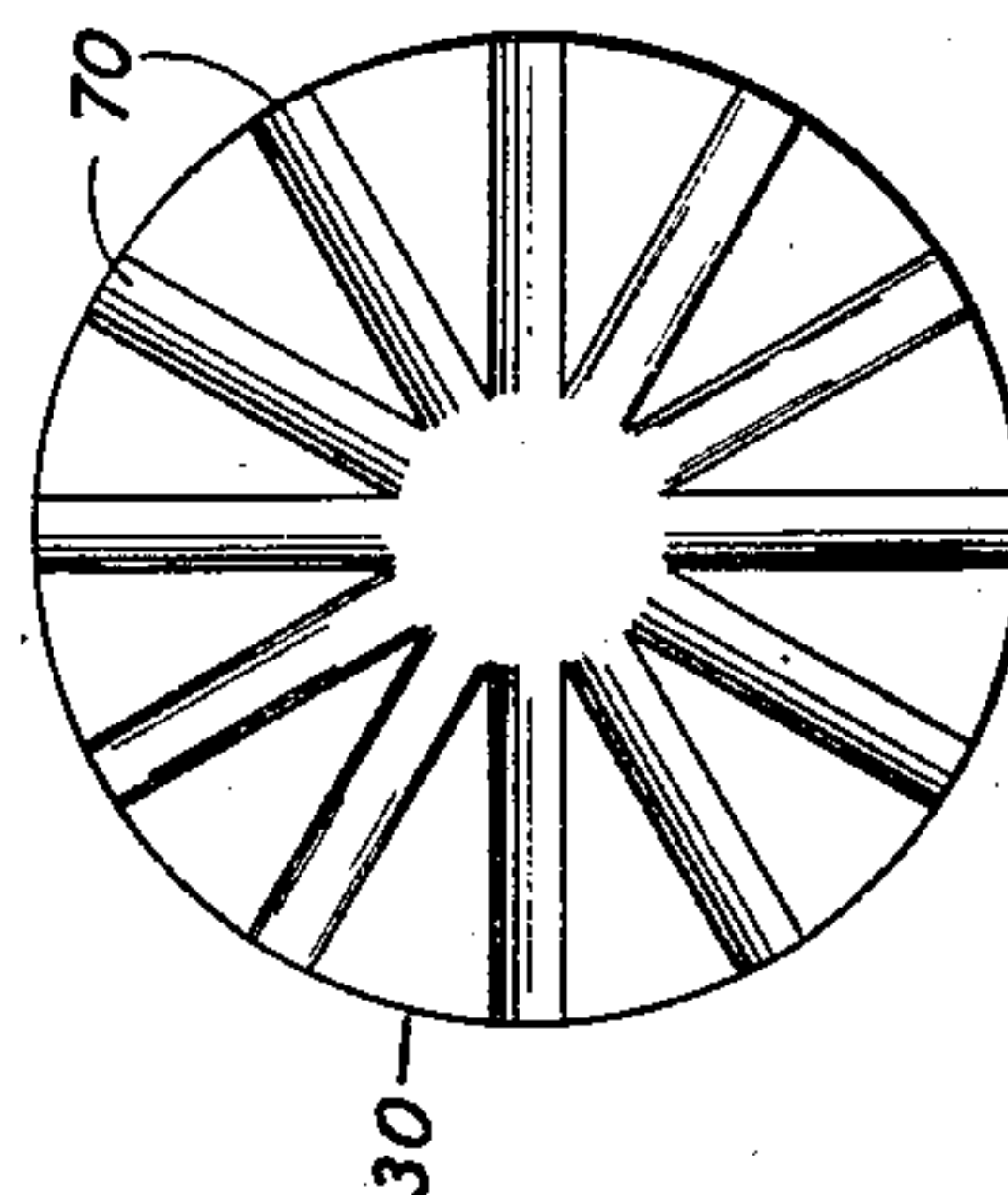


FIG. 7



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UNITED STATES PATENT OFFICE

2,404,784

ACOUSTIC DEVICE

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Application June 7, 1940, Serial No. 339,261

10 Claims. (Cl. 177—386)

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This invention relates to electroacoustic transducers suitable for underwater operation and more particularly to submarine sound receivers and transmitters.

One object of this invention is to provide an electroacoustic transducer adapted for underwater operation and having a broad and uniform frequency range.

Another object of this invention is to provide a submarine type sound translating device, having an electromechanical system, that is both efficient and capable of withstanding high underwater pressures.

One feature of this invention resides in a submarine sound translating device having a vibrating system of low effective mass and stiffness.

In accordance with another feature of this invention, the translating device has a resonant frequency low enough to be critically damped by mechanical motional resistance and by simple damping means employing air or other gaseous material.

A further feature of this invention involves the use of a thin diaphragm and means for balancing the static and low frequency pressures on opposite sides thereof.

An additional feature of this invention resides in a thin domed diaphragm of a diameter sufficient to cooperate with an efficient magnetic system, but having only a restricted portion of its area subjected to water pressure, whereby the water impedance is maintained at a desired value.

Other and further objects and features of this invention will appear more clearly and fully from the following description of illustrative embodiments thereof taken in connection with the appended drawings in which:

Fig. 1 is a sectional view of a receiver illustrating one embodiment of the invention;

Fig. 2 is a section taken on lines 2—2 of Fig. 1;

Fig. 3 is a view partially in section of a receiver like that of Fig. 1 including means for equalizing the pressures on opposite sides of the receiver diaphragm;

Fig. 4 is an enlarged fractional view of the diaphragm showing details thereof;

Fig. 5 is a section on line 5—5 of Fig. 4; and

Figs. 6 to 11, inclusive, show respectively three modifications of a portion of the acoustic elements of the device.

Referring now to the drawings, the receiver designated generally by reference character 10 comprises an annular magnetic structure and a domed diaphragm. The magnetic structure comprises a center pole 11 having a flange 12 at one

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end; a ring-shaped permanent magnet 13 secured to flange 12 and a plate pole 14 attached to the magnet 13. Members 12, 13 and 14 may be secured together by welding or in any other suitable manner. The diaphragm 15, of bronze or other suitable material, has a flange 16 which is clamped between rings 17 and 18 secured to plate pole 14 by fastening means such as screws 19. A depending flange portion 20 of the diaphragm supports the moving coil 21 in the annular air-gap 22 between members 11 and 14. A ring 23 of flexible material, e. g. rubber or the like, or metal, is secured to the diaphragm 15 intermediate its center and flange 16. The outer portion of ring 23 may be secured to a ring 25, as by cementing. The ring 25, which may be of brass or other non-magnetic material, may be fastened to plate pole 14 by means of screws 26. When the receiver is secured to the hull or skin 24 of the vessel, as by bolts 70, the ring 23 is firmly clamped between the hull and ring 25.

That portion of diaphragm 15 lying between the ring 23 and the flange 16 may contain a plurality of orifices 27 which may be provided with flanges 28. Acoustic resistance material, such as felt or silk fabric 29, may be secured over the orifices 27. The flanges 28 may extend inwardly as shown or outwardly, if desired. These flanges 28 are to stiffen the diaphragm around the orifices 27 and may be dispensed with where such stiffening is not necessary. The orifices, flanges and resistance material have been shown somewhat exaggerated as to size in the interest of clarity of illustration.

On the concave side of the diaphragm 15 and secured to center pole 11 is a member 30 which may be of brass or other non-magnetic material. The outer surface of member 30 conforms to the inner surface of the diaphragm and is spaced slightly therefrom. Member 30 serves as a stop to prevent inward collapse of the diaphragm due to extreme pressure or sudden surges caused by waves, underwater explosions, etc. This member 30 also is dimensioned to control the volume of the chamber 31 behind the diaphragm in accordance with desired acoustic characteristics. A plurality of orifices 32 in member 30 connect the chamber 31 to a passage 33 in the center pole 11. Other means than the orifices 32 may be employed to afford communication between chamber 31 and passage 33. For example, a plurality of radial slots 70 may be formed in the bottom of member 30, before it is secured to pole-piece 11 as shown in Figs. 6 and 7; member 30 may be spaced slightly from pole-piece 11 and supported

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on a plurality of studs or pins 72 as shown in Figs. 10 and 11 or by a notched or discontinuous flange 71 as shown in Figs. 8 and 9; or some suitable combination of the foregoing expedients may be used.

Portions of the flexible ring 23, ring member 25, plate pole 14 and diaphragm 15, define an annular chamber 34 on the convex side of the diaphragm. The chambers 31 and 34 may be connected through the acoustic resistance material 29 covering orifices 27.

The stiffness of flange 16 of the diaphragm may be reduced by means of a plurality of overlapping arcuate slots 36, as may be seen in the detail views of Figs. 2, 4 and 5. If it is desired to prevent leakage through slots 36, a thin membrane 37 of suitable material, such as a cellulose plastic may be secured, as by cementing, to flange 16 over said slots. This membrane 37 may be placed on the under or back side of flange 16 as shown in Fig. 5 or on the top or front side of said flange, if desired. In place of membrane 37 a plurality of strips of plastic material may be employed one for each slot 36. If leakage through slots 36 is indicated by the design requirements of the device, they may be left open, or only partially covered as the situation demands.

Connections may be made to coil 21 by suitable means, such as flexible conductors 50, which may be brought out through the clamping rings 17 and 18. These conductors may be connected to leads 51, which may be brought out through the ring 25, being sealed in to prevent leakage from the chamber 34.

A ring or washer 35 of rubber or other suitable material may be secured to center pole 11 and plate pole 14, to close the inner end of the air-gap 22.

The diaphragm may be protected from damage by submerged objects and the like, by means of a grid or screen 60. The member 60 may be secured to the hull of the vessel by any suitable means, such as screws or bolts 61. The orifices 62 in the screen are made large enough so that they have no appreciable acoustic effect on receiver operation.

In the sectional view, Fig. 2, which shows the convex surface of the diaphragm 15, the resilient ring 23 has been omitted in order that details therebehind may be more clearly shown. The region of attachment of this ring to the diaphragm is shown by dot-dash lines on the dome portion of the diaphragm.

Referring to Fig. 3, the passage 33 of the receiver 10 is connected by a tube 40 to a chamber 41. The chamber 41 may comprise a bellows 42 of bronze or the like, secured in a housing 43 by a cover 44. The bottom portion of housing 43 may be connected to the water outside of the vessel by means of a pipe 45 suitably secured to the hull at orifice 46 as by flange 47.

The water pressure outside of the vessel is transmitted to receiver chamber 31 and hence to the back of the diaphragm 15 via orifice 46, pipe 45, interior of housing 43, bellows 42, chamber 41, tube 40, passage 33, orifices 32 to chamber 31. Since the front of the diaphragm 15 is also subjected to the water pressure, the foregoing means provides for equalization of pressure on the opposite sides thereof. The impedances of the tubes, pipes, chambers, etc., comprising the equalizing system, are such that it acts as a low-pass filter. The static pressure and low frequency pressures, such as are caused by waves, etc., are thus equalized. Pressures at sound frequencies,

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on the other hand, are sufficiently attenuated to prevent their equalization, allowing actuation of the diaphragm in response thereto.

The chambers 34, 31, 41 and the various passages interconnecting said chambers may be filled with a suitable fluid, preferably gaseous material, such as air or nitrogen.

When the diaphragm 15 vibrates, the fluid in chambers 31 and 34 is forced back and forth through the acoustic resistance means 29. By employing air or a gas as the fluid, mechanical damping which is independent of temperature is thus afforded. The chambers 31 and 34 and the acoustic resistance material 29 are proportioned to give the required damping effect at low frequencies near resonance. Venting of the diaphragm through the orifices 27 reduces chamber stiffness and permits a low resonant frequency.

In a device of this type the diaphragm should be big enough so that a suitable magnetic system may be associated therewith; but not so large that the mechanical impedance of the water too greatly exceeds that of the vibrating system, which would result in inefficient conversion. With the type of instrument disclosed, having a low resonant frequency, the velocity

$$\dot{\xi}$$

of the vibrating system at high frequencies will be determined by the mass reactances X_R of the water and X of the vibrating system as a whole, respectively. Thus,

$$\dot{\xi} = \frac{f}{X_R + X} \quad (1)$$

where

f —the force produced by the sound effective at the diaphragm.

The force f for a given sound water pressure is proportional to the diaphragm area or the square of its radius r ; the reactance X_R is proportional to the cube of the diaphragm radius. Thus,

$$\dot{\xi} = \frac{K_1 r^2}{K_2 r^3 + X} \quad (2)$$

For a given value of X there is an optimum value of r to obtain maximum velocity. Differentiating Equation 2 with respect to r gives

$$\frac{d\dot{\xi}}{dr} = \frac{(K_2 r^3 + X) 2K_1 r - K_1 r^2 (3K_2 r^2)}{(K_2 r^3 + X)^2} = 0$$

$$(K_2 r^3 + X) 2K_1 r = K_1 r^2 (3K_2 r^2)$$

$$2K_1 K_2 r^4 + 2K_1 X r = 3K_1 K_2 r^4$$

$$2X = K_2 r^3$$

Since

$$X_R = K_2 r^3$$

$$2X = X_R$$

The water mass then should be twice the mass of the vibrating system to obtain maximum velocity. This desirable relationship can be realized with a light and efficient vibrating system by restricting the area of the diaphragm exposed to the water.

The foregoing specific description has, for convenience, been restricted to a submarine sound receiver. However, a transducer such as is contemplated by this invention may also be employed as a submarine sound transmitter. When used as a sound transmitter or radiator, the damping resistance at the diaphragm orifices 27 should be made low, the diameter of said orifices large, and the volume of the chamber of the con-

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cave side of the diaphragm large as compared with a receiver. These changes will result in a lower resonance frequency above which the velocity of the diaphragm will vary inversely with frequency and closely compensate for the quadratic increase with frequency in the radiation or loading resistance of the water. Substantially uniform acoustic output will then result.

Although specific embodiments of this invention have been shown and described, it will be understood that modifications may be made therein without departing from the scope and spirit thereof as defined by the appended claims.

What is claimed is:

1. A submarine sound receiver comprising a structure including magnet means, a domed diaphragm attached to said structure, an electrical current conductor secured to the diaphragm and located in the field of said magnet means, stop means secured to said structure and spaced from the inner surface of the diaphragm to define therewith a chamber, flexible means secured to the outer surface of the diaphragm to restrict the area thereof subjected to exterior pressure, said flexible means, diaphragm and structure defining a second chamber, and acoustic resistance means, associated with the diaphragm and connecting the two chambers.

2. An acoustic transducer comprising a structure including means for producing a magnetic field, a domed diaphragm secured to said structure and defining therewith an acoustic chamber, an electrical current conductor attached to the diaphragm and positioned in said field and resilient means secured to said structure and diaphragm for restricting the area of the diaphragm subjected to sound pressure, a portion of the resilient means and the diaphragm defining with said structure a second acoustic chamber, said diaphragm having acoustic resistance orifices therein connecting the two acoustic chambers.

3. An acoustic device for operation in a sound transmitting medium more dense than air, comprising a structure including magnetic field producing means, a non-magnetic diaphragm having a stiff, convex central portion and a resilient outer portion connected to said structure, a sound current coil secured to the diaphragm in cooperative relation with the magnetic field producing means, means for restricting the area of the diaphragm subjected to the pressure of the sound transmitting medium, acoustic impedance chambers on opposite sides of the diaphragm, said restricting means cooperating with a portion of the diaphragm to define one of said impedance chambers, and acoustic resistance means secured to the diaphragm and connecting the impedance chambers.

4. An acoustic device for underwater operation comprising a structure, an outwardly convex, domed diaphragm cooperating with said structure to define a chamber, means in front of said diaphragm for restricting water pressure to a portion thereof, said means cooperating with the structure and diaphragm to define another chamber, and means defining restricted passages between said chambers.

5. A submarine sound translating device comprising a structure, an outwardly convex, domed diaphragm resiliently attached to said structure and defining with said structure a chamber, a resilient ring secured to the convex surface of the diaphragm dome and to the structure for confining water pressure to a restricted portion of the diaphragm, a second chamber behind said resilient means and outside of the diaphragm

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dome, and acoustic resistance means on said diaphragm and interconnecting the chambers.

6. A submarine sound receiver comprising a structure including magnetic means having pole-pieces defining an annular air-gap, a diaphragm of non-magnetic material and having a thin, convex portion, a resilient peripheral flange, and a depending flange, a sound current coil mounted on said depending flange, said peripheral flange secured to a pole-piece to position the coil in the air-gap, said diaphragm and structure defining a chamber, and a ring of resilient material secured at its inner edge to the convex side of the diaphragm intermediate the center and the peripheral flange and having its outer portion secured to said structure, a portion each of said ring, diaphragm and structure defining a second chamber, said portion of the diaphragm having acoustically resistant orifices connecting the two chambers.

7. A submarine sound receiver comprising a structure including magnetic means having a center pole, and a plate pole spaced therefrom to define an annular air-gap, a diaphragm of non-magnetic material having a thin, central dome portion and a resilient supporting flange secured to said plate pole, a sound current coil secured to the diaphragm and positioned in the air-gap, a stop member secured to the center pole and having its outer surface conforming to the inner surface of the diaphragm dome and spaced slightly therefrom to define a chamber, a resilient ring attached to the structure and secured to the exterior surface of the diaphragm dome intermediate its center and edge to restrict the area thereof in contact with water pressure, a portion each of the resilient ring, the diaphragm and the structure defining a second chamber, and acoustic resistance means associated with orifices in said diaphragm, and connecting said chambers.

8. A submarine sound receiver comprising a magnet structure including a pole-piece, an outwardly convex diaphragm of thin non-magnetic material having an electrical current conductor secured thereto in cooperative relation to said pole-piece, resilient means secured to said diaphragm and associated with said structure to confine a restricted portion of said diaphragm to external pressure and to define with said diaphragm and structure a chamber on one side of said diaphragm, a chamber on the other side of the diaphragm, and acoustic resistance means connecting said chambers together through said diaphragm.

9. A submarine sound receiver comprising a structure including magnetic means having a center pole, and a plate pole spaced therefrom to define an annular air-gap, a diaphragm of thin non-magnetic metal having a central, outwardly convex dome portion and a resilient supporting flange portion secured to said plate pole, a sound current coil secured to the diaphragm and positioned in the air-gap, an outwardly convex stop member secured to said center pole, spaced from the dome portion of the diaphragm and defining therewith a chamber, a ring of rubber-like material secured to said structure and to the convex side of the diaphragm, intermediate the center and the supporting flange thereof, to limit a portion only of the diaphragm dome to external pressure, a portion each of the ring, the structure and the diaphragm defining a second chamber, behind said ring and outside of the diaphragm, the portion of the diaphragm between the ring and flange containing perforations through which said chambers are interconnected, and acoustic re-

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sistance material secured to the diaphragm over said perforations.

10. A submarine sound translating device comprising a structure, an outwardly convex, domed diaphragm resiliently attached to said structure and defining with said structure a chamber, flexible means secured to the convex surface of the

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diaphragm dome and to the structure for confining water pressure to a restricted portion of the diaphragm, a second chamber behind said flexible means and outside of the diaphragm dome, and means including acoustic resistance interconnecting said chambers.

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