

April 12, 1932.

B. OLNEY

1,853,174

SOUND REPRODUCING DEVICE

Filed Oct. 22, 1927

2 Sheets-Sheet 1

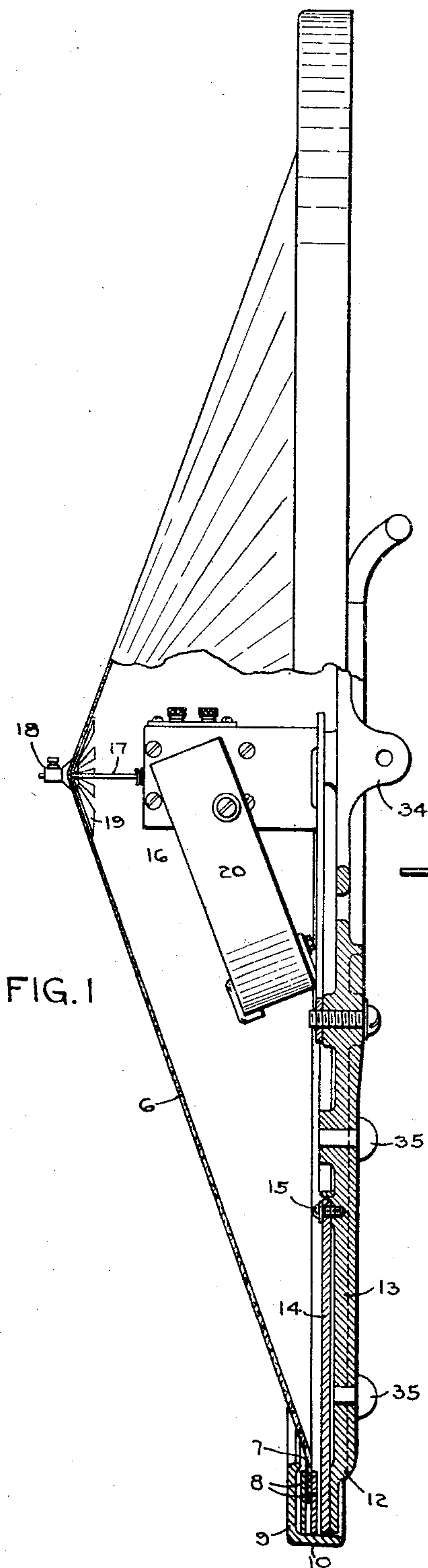


FIG. 1

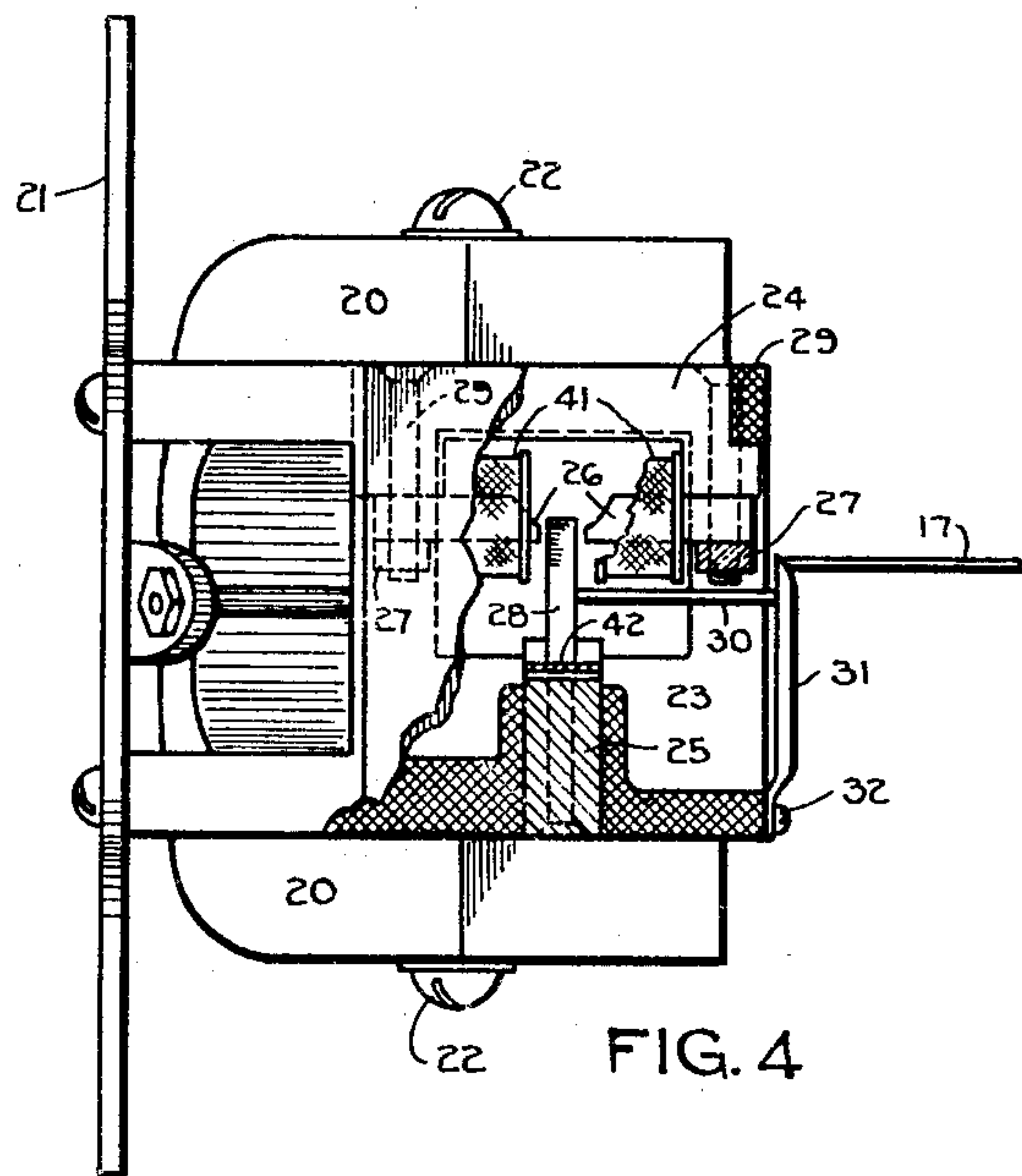


FIG. 4

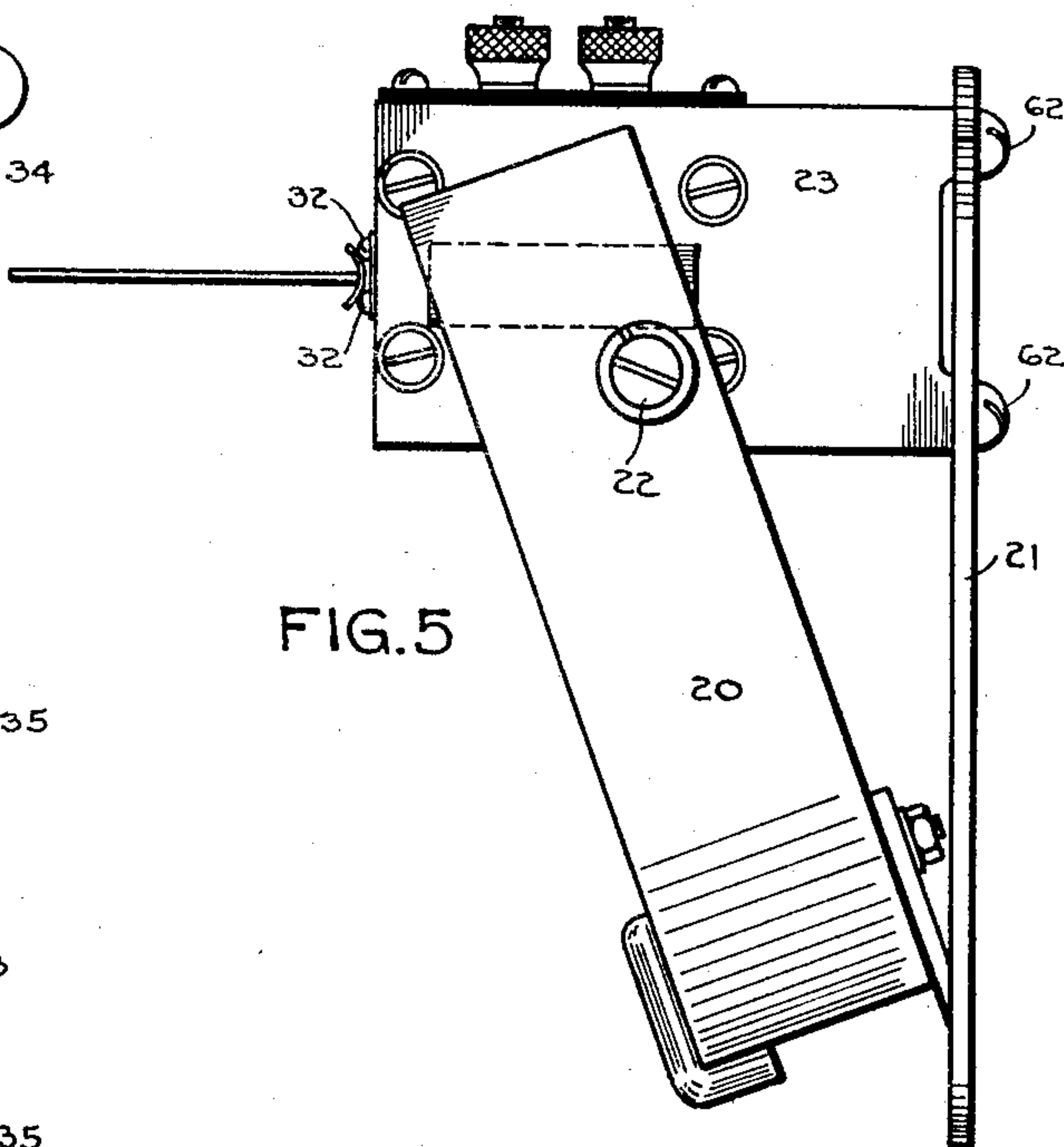


FIG. 5

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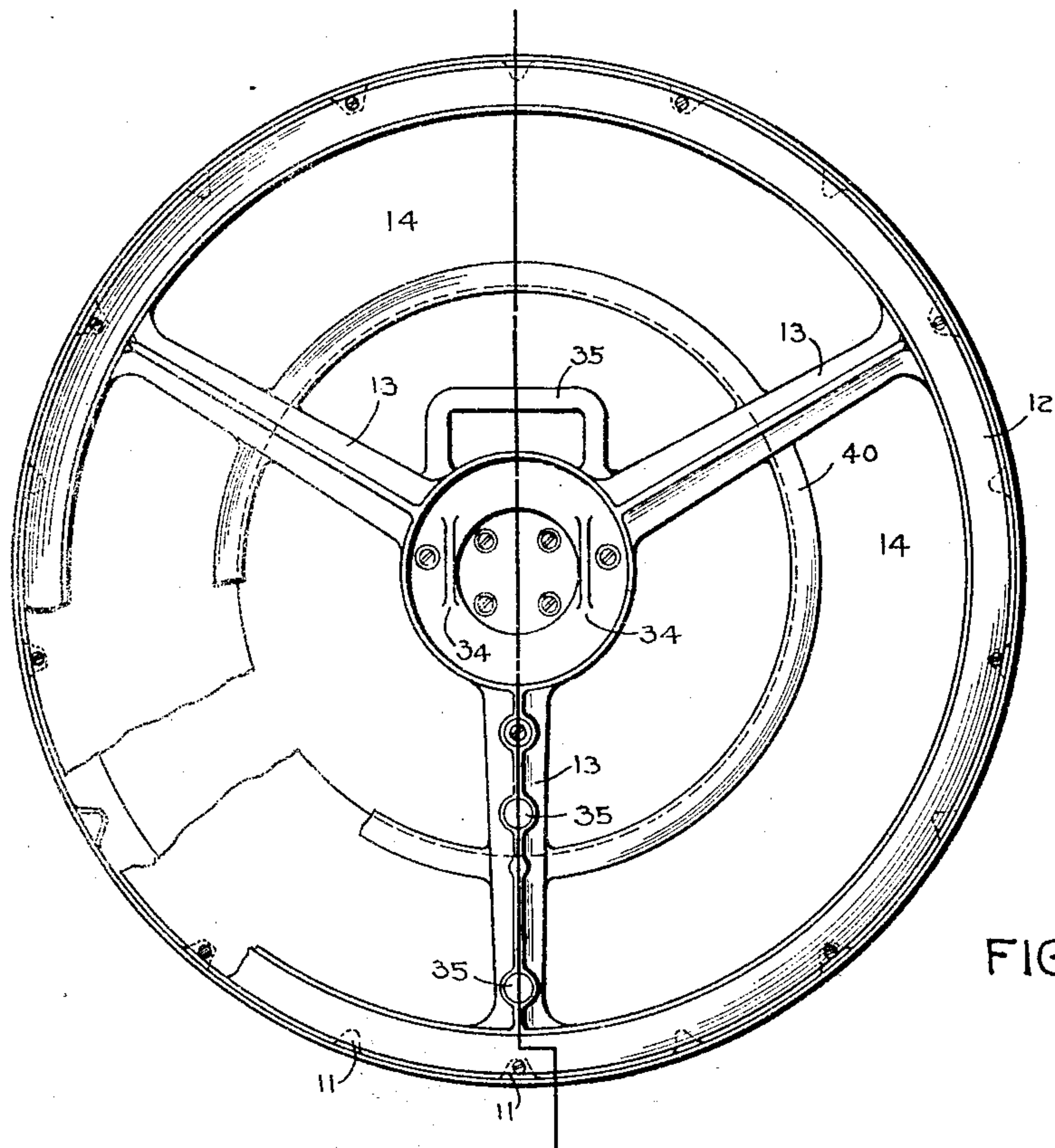


FIG. 2

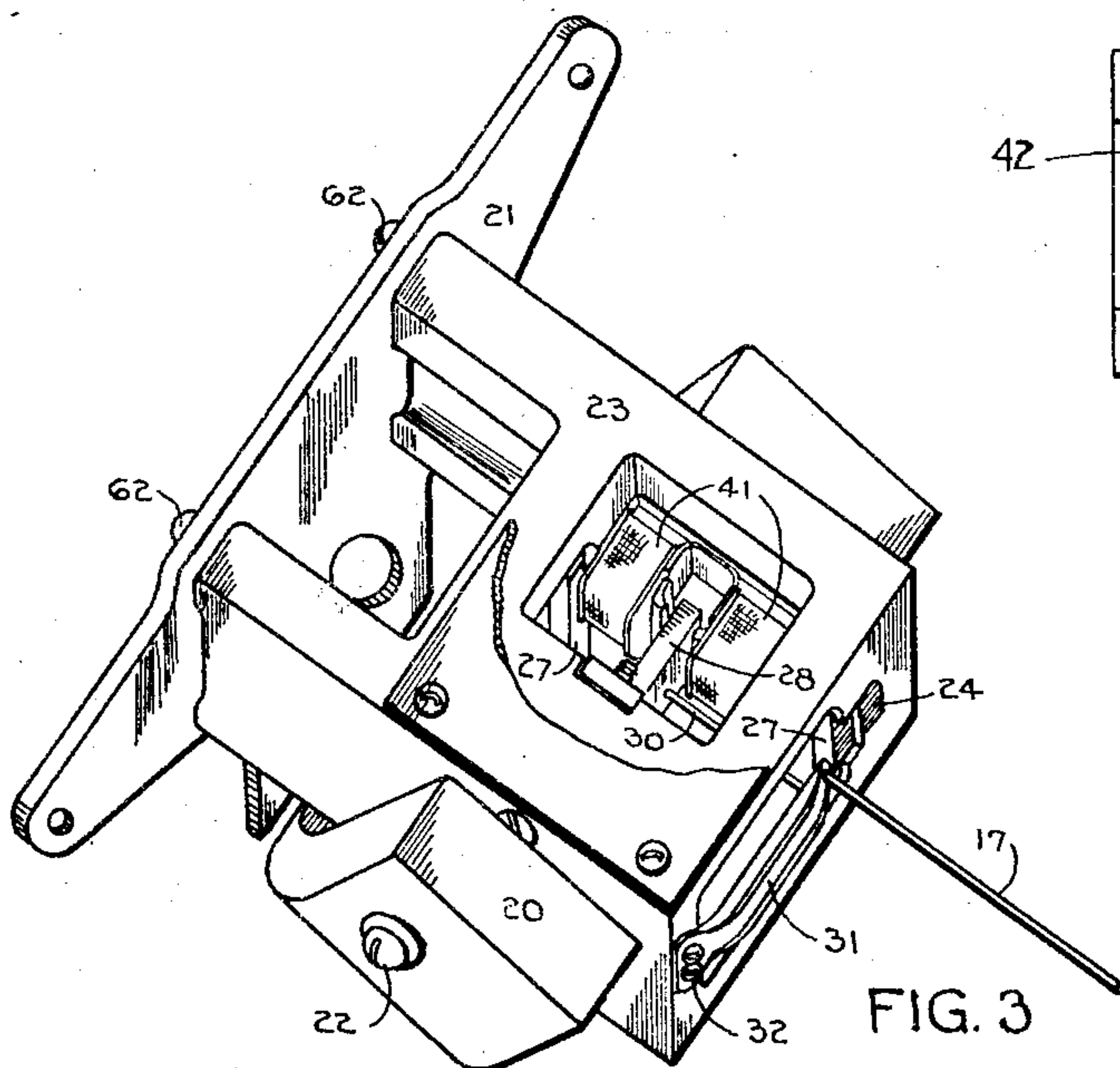


FIG. 3

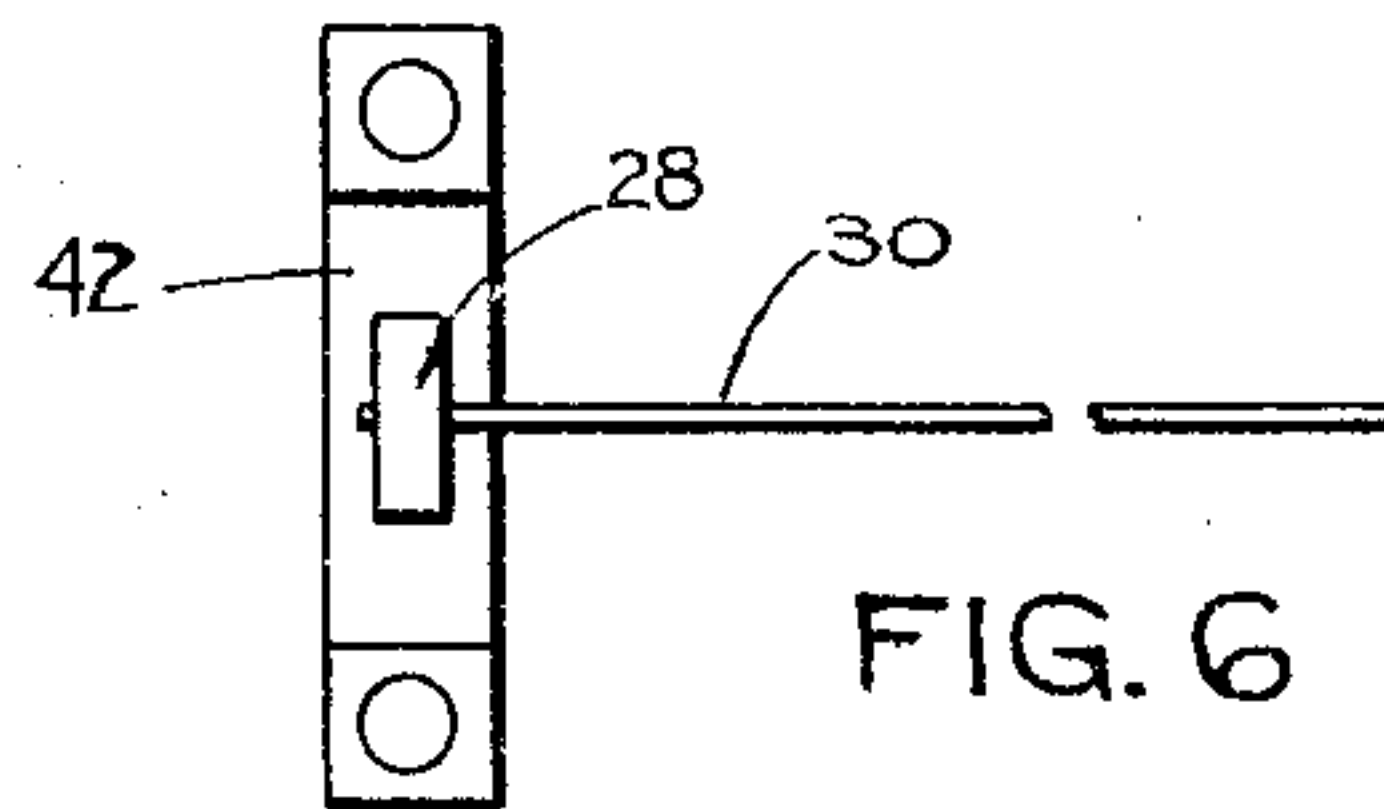


FIG. 6

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SOUND REPRODUCING DEVICE

Application filed October 22, 1927. Serial No. 228,020.

This invention relates to sound reproducing devices and more particularly to sound reproducing devices in which conical diaphragms are employed. It has been found especially difficult in former designs of sound reproducing devices to manufacture a device which would faithfully reproduce signals throughout the audible range from the lowest frequency to the highest frequency. Various expedients have been resorted to such as providing one sound reproducing device for a band of frequencies in the upper register and another device for reproducing the remaining band of frequencies in the lower register. These expedients have not been satisfactory since it is found that the signal reproduced is usually deficient in certain portions of the frequency range so that either the bass notes or the high-pitched notes were exaggerated which resulted in unfaithful reproduction. Furthermore, it has been found in sound reproducing devices where a conical diaphragm of paper is employed that undesired noises are developed which are commonly referred to as "paper rattle". It has also been noted that the driving unit tends to introduce foreign noises due to undesired vibrations of its driving rod which result in a noise referred to in the art as "singing".

The present invention has for its purpose the production of a sound reproducing device of sturdy construction in which the frequency range in the lower register is extended downward and the purity of the notes at low frequencies is improved without sacrificing the higher frequencies while strong resonances especially at low frequencies are removed. In addition so-called "paper rattles" are eliminated and the tendency of the driving rod to "sing" is reduced. The design of the device herein disclosed simplifies the process of manufacturing and assembling and thereby produces a device which is efficient and still relatively inexpensive.

Other features of the invention will appear from the detailed description and appended claims.

Referring to the drawings, Fig. 1 represents a side elevation of the sound reproducing device of the present invention with a por-

tion of its structure broken away for clearness in illustration. Fig. 2 is a rear view of the structure of Fig. 1 also having a portion broken away. Figs. 3, 4, 5 and 6 represent different views of a driving unit, Fig. 3 being a perspective view partially broken away, Fig. 4 a top view partially in section, Fig. 5 a side view, and Fig. 6 is a detail view of the reed and a portion of the driving rod system.

Referring especially to Figs. 1 and 2 there is represented a conical diaphragm 6 of waterproofed, fibrous material gradually increasing in thickness from its apex to its periphery and provided at its outer edge with a flat annular rim or flange 7 on each side of which there is attached by glue or other suitable means a notched layer of felt or other non-resonant material 8. The diaphragm is mounted in a heavy frame of metal consisting of a ring 9 having a flange 10 and provided with bosses 11, certain of which are threaded. This frame also includes a back portion including two concentric rings 12 and 13 molded integral with three equally spaced spider arms 14 converging to a hub. The second portion of the frame is attached to the ring 9 by screws threaded through the ring 12 into the bosses 11. These bosses together with screws 15 engaging the back portion of the frame serve, to hold an annular baffle board or plate 16 (which may be laminated) in position, closing a portion of the open end of the diaphragm 6 for a purpose which will be further described. At the hub of the frame there is mounted a driving unit generally designated 17 which is provided with a driving rod 18 passing through the apex of the cone where a washer engaging the outer surface of the diaphragm is locked in position by a sleeve and lock screw 19 engaging the driving rod. A conical star-shaped washer 20 serves to reinforce the inner surface of the apex of the diaphragm.

The driving unit 17, as shown in Figs. 3, 4 and 5, includes a horseshoe magnet 21 supported in inclined position on a mounting plate 22 which in turn is attached to the hub of the frame. Between the free ends of the horseshoe magnet there is secured by screws

such as 22 and 62 a frame 23 of diecast material, the faces of which frame are flat and parallel to engage the inner surface of the free ends of the horseshoe magnet. A yoke 24 of laminated magnetic material is cast as an insert within this frame in such position that it is in physical engagement with one of the free ends of the horseshoe magnet, while a solid block 25 of magnetic material is also cast as an insert in the frame in such a position that it physically engages the other free end of the horseshoe magnet. It will be noted from Figure 4 that each lamination of the yoke 24 is substantially U-shaped and that on each of the free ends of the yoke laminated pole pieces 26 having tapered ends are adjustably clamped in position by saddles 27 so that they may be adjusted with relation to armature 28 of magnetic material and still be locked in adjusted position so that there will be no creeping motion during the tightening of binding screws 29 during factory adjustment. The armature 28 is connected by a rod 30 to the free end of a rigid member 31 secured by screws 32 to the diecast frame. At the extreme end of the member there is mounted the driving rod 17. It will be noted that the horseshoe magnet 20 is supported on the frame in inclined relation parallel to the surface of the diaphragm so that the driving unit is in especially close relation to the apex to permit the use of a driving rod 17 of minimum length.

The reproducing device may be mounted on a pedestal after the manner of a tip table by means of a bolt, not shown, passing through the apertured lugs 34 on the rear of the frame while a handle 35 is provided for moving the device without injuring the diaphragm. The apertured lugs 34 may also serve as a means for supporting the device on a wall bracket (not shown) while rubber buttons 35 prevent the lower part of the frame from engaging any supporting surface which might be set into vibration by the operation of the device.

The improvement in quality of reproduction resulting from the use of a reproducing diaphragm of varying thickness is believed to be due to the following reasons although the invention is not to be limited by this theory. When a vibratory driving force is applied to the apex of a conical diaphragm the whole diaphragm vibrates as a unit plunger, provided the proper relations exist between the frequency of the driving force and the stiffness, mass and area of the cone. The rim or flange 7 acts as a stiffener for the edge of the diaphragm so that it may act as a unit plunger at low frequencies. As the frequency is increased a point is reached at which the diaphragm no longer vibrates as a unit but passes into flexural vibration. In this latter type of motion, waves travel outwardly from the apex of the diaphragm. Also the dia-

phragm may vibrate in segments, the number and disposition of which vary with the frequency. These segments are separated by nodal lines or lines of no motion and the phase of vibration changes 180 degrees as each of these nodal lines is crossed, that is, if one segment be moving outward, the adjacent segment will simultaneously be moving inward. The diaphragm has a resonant point at a frequency in each of these modes of vibration at which with constant driving force, it gives an increased response. With ordinary thin paper diaphragm these resonances are often accompanied by series of wave form distortion particularly at the lower frequencies where the amplitude of motion is large. This wave form distortion appears to result from sounds extraneous to those which it is sought to reproduce which are generated by reason of the segments snapping back and forth on each side of the nodal lines in somewhat the same manner as the bottom of an ordinary oil can. The noises thus produced in loud speakers are commonly referred to as "paper rattles". If the diaphragm be made of a rather thick material having a high degree of internal damping, the tendency to rattle in the above manner may be very much reduced and by properly mounting the diaphragm, may be entirely eliminated. However, when the entire diaphragm is made of such thickness it becomes difficult to radiate the higher frequencies for the following reason: In the type of motion referred to above where flexural waves are produced, the waves tend to travel to the edge of the diaphragm and there, being reflected, return toward the center or apex. If the internal losses in the diaphragm material due to friction between its component fibers be high, the waves at the higher frequencies become extinguished before reaching the outer edge of the diaphragm. Consequently at the high frequencies only a portion of the diaphragm surrounding the apex is in active vibration with the result that the effective mass of the diaphragm is much reduced at high frequencies. It is therefore evident that any expedient which will still further reduce the effective mass of the diaphragm at high frequencies will result in a substantial increase in the response at these frequencies because the percentage reduction in total mass of the vibrating system will be greater than would be the case, were the entire diaphragm in motion. It follows from the above reasoning that a very light thin diaphragm is desirable to obtain good high frequency response but that such a diaphragm is very prone to rattle at low frequencies at some of its resonance points.

In an attempt to obtain the good high frequency response of a thin diaphragm and the good low frequency response of a thick diaphragm, applicant has found that a dia-

phragm of thin paper for a portion of the diaphragm near the apex and thick heavy paper for the remainder of the diaphragm possessed certain undesirable characteristics.

5 Such a conical diaphragm is quite efficient at the higher frequencies but produces paper rattle at certain other frequencies. This difficulty seemed to be caused in a large measure by the abrupt change of impedance of the
10 diaphragm to wave motion at the junction of the light and heavy diaphragm materials. At the frequencies where the paper rattle was very pronounced the junction between the two kinds of material was usually found to be at
15 a loop or line of maximum amplitude of diaphragm motion.

Satisfactory results have been obtained with diaphragms progressively increasing from a thickness of .020" at the apex to .030" at the edge of the diaphragm although applicant is not to be limited to these thicknesses. It would be desirable to have these diaphragms even thinner at the apex but it is difficult to secure this condition in manufacture and the diaphragms would be especially
25 fragile for shipment and use.

It has been pointed out that the diaphragm 6 of varying thickness has notched, ring-shaped pads of light resilient felt or similar nonresonant material cemented to both sides of the flat flange of the diaphragm. The purpose of these felt pads is to prevent the diaphragm from striking the metal rim in which it is mounted when being driven at
35 high amplitude. These felt pads also serve to support the diaphragm in a vertical position on the flange 10 to prevent the weight of the diaphragm from bending the driving rod downward. The felt pads are attached directly to the diaphragm rather than to the metal rim for it has been found that in case
40 there is relative motion between the diaphragm and the felt pads a rushing sound is radiated from the diaphragm when there are large movements of its edge on low frequency notes. This rushing sound is due to friction between the felt and the diaphragm setting up vibrations in the diaphragm. When,
45 however, the felt pads are fastened to the diaphragm this friction occurs between the pads and the metal rim but negligible vibration is transmitted to the diaphragm because of the high damping introduced by the felt.

It has also been pointed out that an annular baffle board 14 of rigid laminated fibrous material partially closes the open side or back of the conical diaphragm. The purpose of this baffle board is to aid in creating an air-cushioning effect at the rear of the diaphragm in order to restrain it from excessive amplitude of vibration particularly at resonant points in the low frequency range. This baffle has little or no effect upon the radiation of vibrations outside of those occurring at these low resonance points.
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It has been stated that the frame consists of two members, one with spider arms 13 provided with two concentric rings which the baffle board 14 engages and which serve to rigidly support it. This rigid support of the
70 baffle board is important because it is desired that vibration of the baffle board be restrained as completely as possible. The other member of the frame consists of a ring bearing, a rearwardly projecting flange, and which is
75 adapted to fit the spider member above mentioned. The series of bosses 11 on the inner side of the ring serve to separate it from the back member thus forming an annular channel in which the felted edge of the cone may
80 fit loosely.

From the description of the driving unit it will be noted that one of the important features of the invention incorporated therein is a one piece diecast frame of nonmagnetic material in which frame there is cast as inserts a laminated yoke of magnetic material and a solid block of material on the other side which together form parts of the magnetic circuit. This method of construction fixes the important parts of the unit in proper relation to each other and is a marked improvement over the previous method of construction in that jars and shocks cannot change the adjustment, and assembly is greatly simplified.
85

Another feature is the laminated pole pieces of magnetic material which are slidably adjustable with relation to the armature. These pole pieces are clamped firmly in place by saddles which are designed so that there will be no creeping motion in the course of tightening of the binding screws during factory adjustment.
90

The flexible steel reed 42 upon which the armature is mounted must have a certain optimum stiffness for best operation. It is difficult, if not impossible, to attain the required stiffness by the use of materials of commercial dimensions and temper, therefore in this speaker it is proposed to permanently adjust the stiffness of this reed in the factory by grinding its edges, thus attaining a uniformity of product which is very desirable.
105

The horseshoe magnet of the driver unit is mounted with its ends embracing the diecast frame thereof and making contact with the magnetic pieces cast into the frame. The loop of the magnet is tilted backward and fastened to the driver element mounting plate 21. This tilting of the magnet is very desirable because it allows the whole driver element to be located nearer the apex of the cone than otherwise would be the case, permitting a very short drive rod to be used which reduces the liability of "singing" sounds due to this part.
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The flux path and the general action of the driver element will now be described. Starting at one pole of the horseshoe magnet 20 the
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125
130

flux is carried to the root of the armature 28 through the solid block of magnetic material 25 cast into one side of the frame. At the tip of the armature the flux divides into two equal parts, each part crossing the air gap between the armature and a pole tip, then continuing through the pole pieces 26, laminated yoke 24 and back to the other pole of the permanent magnet. Each pole piece bears half of the operating winding. The direction of winding of these coils 41 is such that when current passes through them in a given direction the flux in one pole tip is weakened while that in the other pole tip is increased. This causes the armature to move toward the pole piece having the greater flux density. When current is sent through coils in the opposite direction the armature, of course, will move in an opposite sense.

The force acting upon the armature may be resolved into two components. One is due to the current in the operating coils and the other is due to the steady flux from the permanent magnet. This latter force is brought into play only as the armature is deflected from its normal position and is opposed by the stiffness of the reed upon which the armature is mounted. It is desirable that the relation between this second force and deflection be linear in order that distortion may be obviated. This result is substantially attained in the present construction by so proportioning the magnetic circuit that the armature is saturated at the root when in its normal position. The area of the pole pieces is so proportioned that they cannot be saturated by the normal flux but, in order to prevent the armature from being permanently attracted to a pole piece 26 at the limit of an extreme swing, the area at the pole tip is reduced to approximately $\frac{1}{3}$ that of the pole piece proper. The effect of this is to cause the pole piece to saturate at the tip only at extreme swings of the armature, thus limiting the attraction at this point and preventing the armature from approaching the pole piece too closely and sticking thereto. By suitable proportioning, the above is accomplished without causing the deflection-force characteristic to depart substantially from a linear relation during the greater part of working range of the armature. The preservation of this linear relation contributes materially to the production of pure low tones which previously has not been attained in electro-magnetic driver elements.

Another feature of this magnetic circuit is that on account of normal saturation of the armature it undergoes little or no change in flux density during any part of its excursion. As a consequence, the path of the alternating flux is through the laminated yoke, pole piece, working air gaps and transversely through the armature tip. With the exception of the later element and the air gaps this entire flux

path is comprised of magnetic material of high permeability and low losses which contributes to high efficiency.

What I claim, is:

1. In a sound reproducing device, a conical diaphragm provided with a flange, said diaphragm tapering in thickness along all lines to its apex from said flange, and means including nonresonant material for supporting said diaphragm at said flange.
2. In a sound reproducing device, a conical diaphragm gradually increasing in thickness along all lines from its apex to a point near its periphery, nonresonant material attached to the periphery of said diaphragm, and a frame engaging said nonresonant material to support said diaphragm.
3. In a sound reproducing device, a frame, an annular baffle board mounted on said frame, a conical diaphragm formed of fibrous material increasing in thickness along all lines from its apex to its periphery, the axis of said cone coinciding from the center of said baffle board, and a driving unit mounted in the space between said baffle board and said diaphragm for moving said diaphragm with respect to said baffle board.
4. In a sound reproducing device, a conical diaphragm tapering in thickness from its periphery along all lines extending generally toward the same point, and means including nonresonant material for supporting said diaphragm near its periphery.
5. In a sound reproducing device, a diaphragm generally conical in form, said diaphragm tapering in thickness along all lines from its periphery toward its smallest dimension, and means including nonresonant material for supporting said diaphragm near its periphery.
6. In a sound reproducing device, a diaphragm generally conical in shape, actuating means attached to said diaphragm at its smallest area, and means including nonresonant material for supporting said diaphragm near its periphery, said diaphragm tapering in thickness along all lines from its periphery toward said actuating means.

In witness whereof I hereunto subscribe my name this 21st day of October, A. D. 1927.

BENJAMIN OLNEY.