June 15, 1937. A. I. ABRAHAMS 2,083,537

ELECTROACOUSTICAL TRANSLATING DEVICE

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Fig. 1

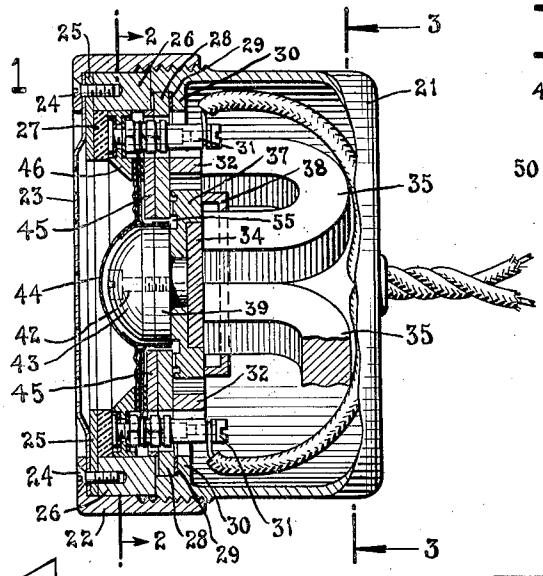


Fig. 1a

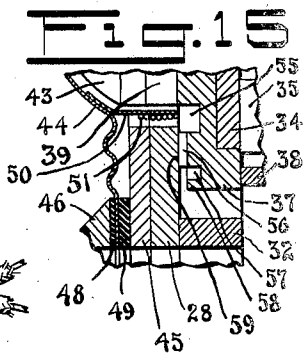


Fig. 4

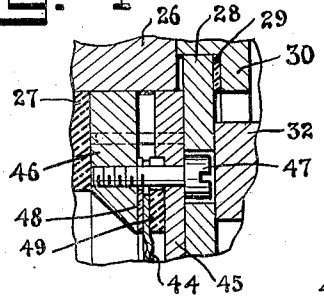


Fig. 3

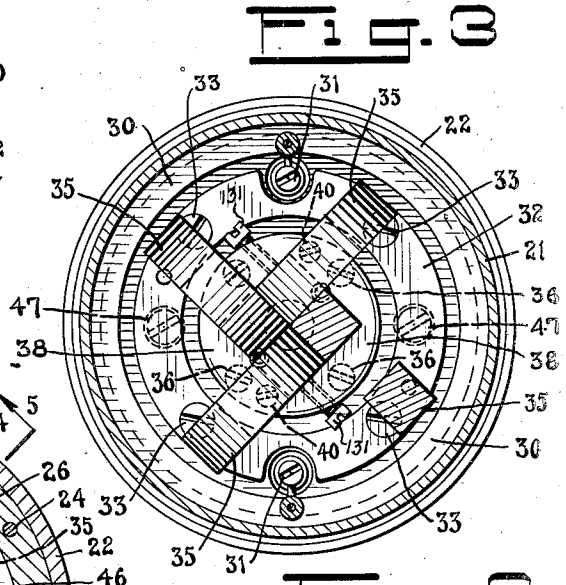


Fig. 2

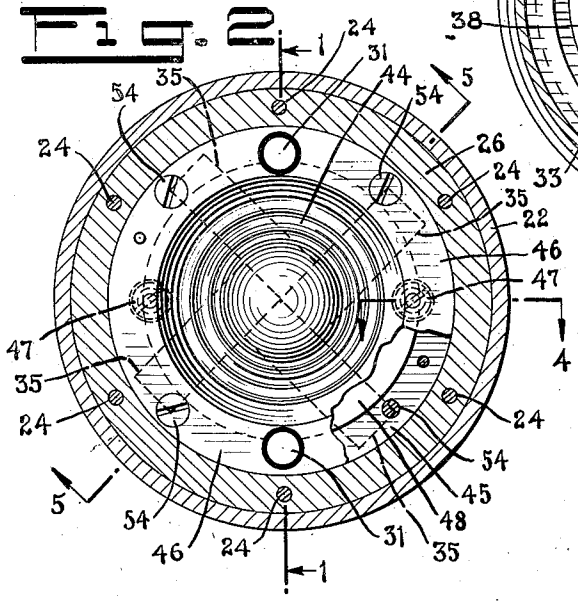
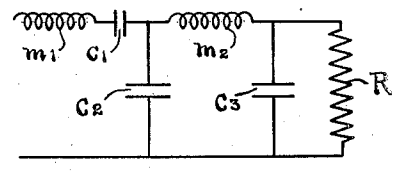


Fig. 8



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Fig. 5

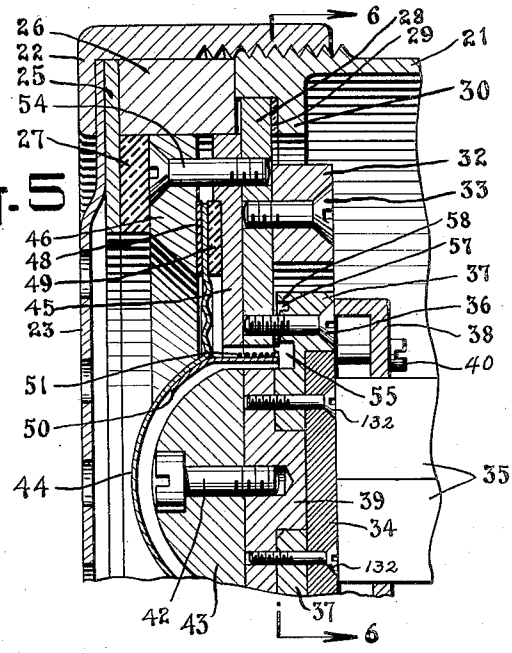


Fig. 7

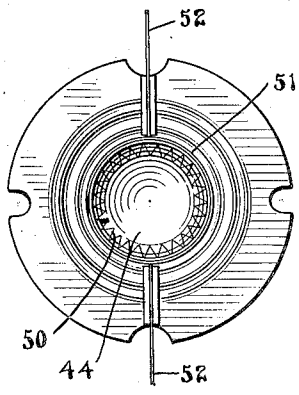
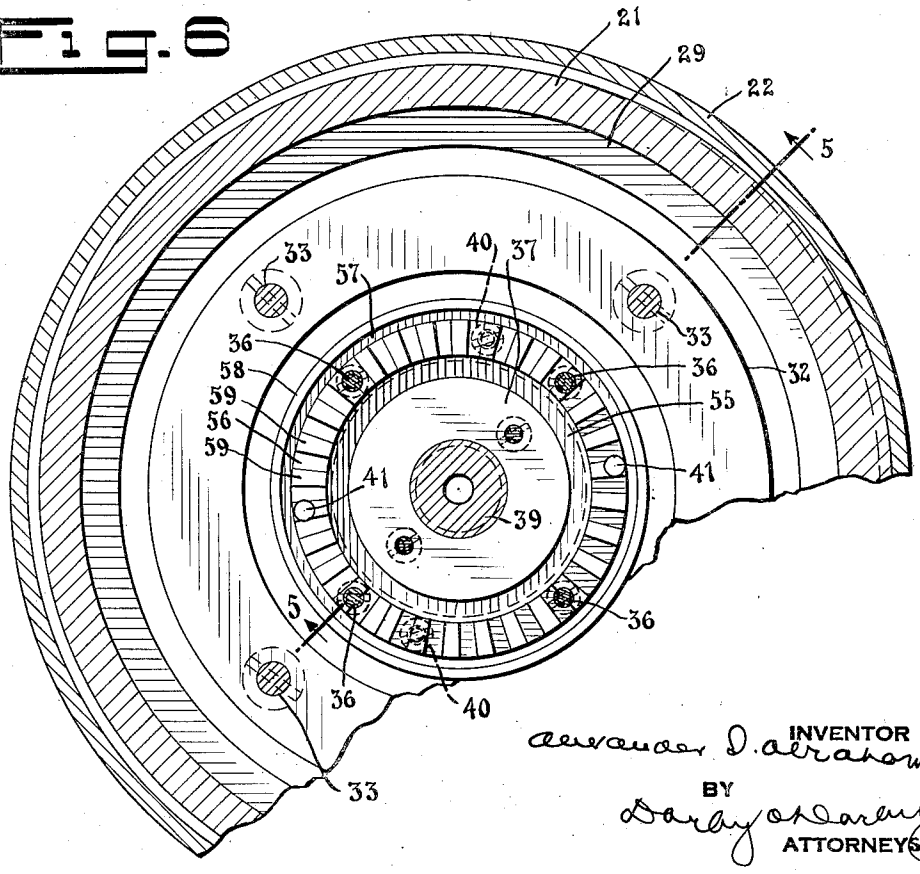


Fig. 6



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Fig. 9

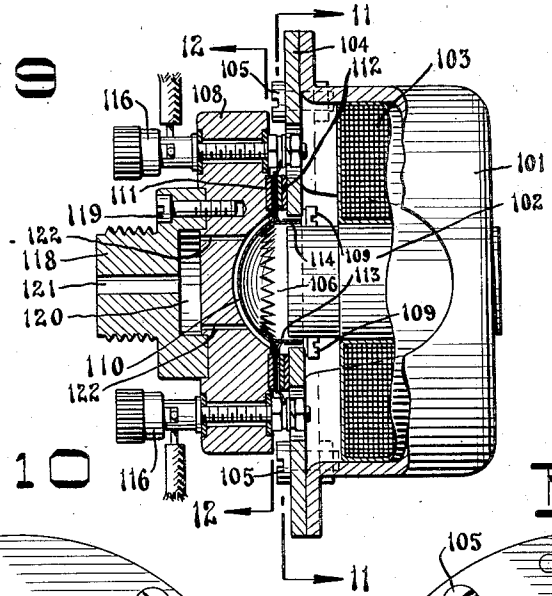


Fig. 14

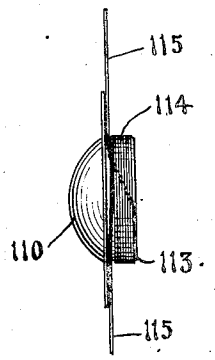


Fig. 10

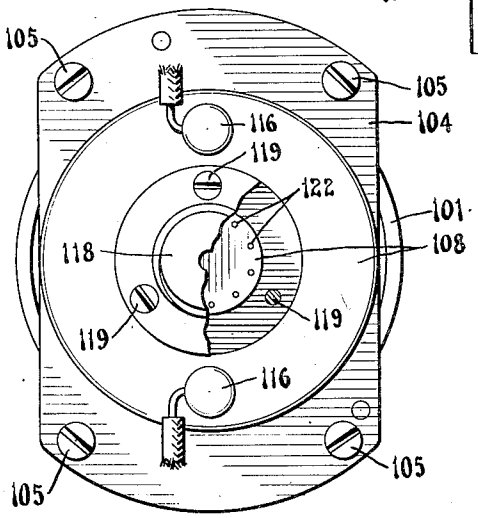


Fig. 11

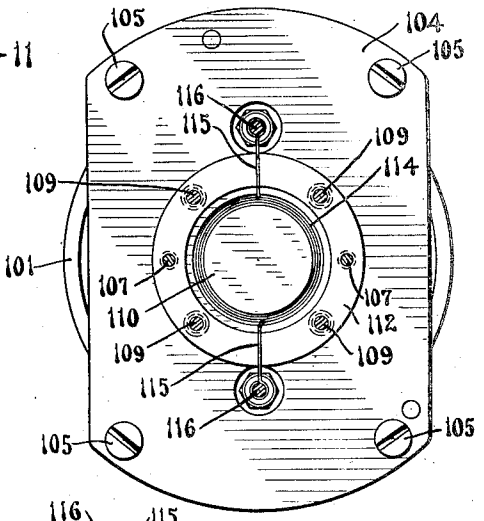


Fig. 12

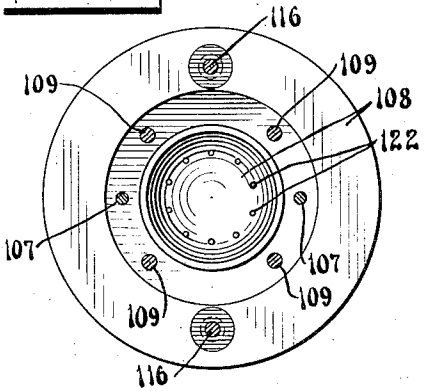
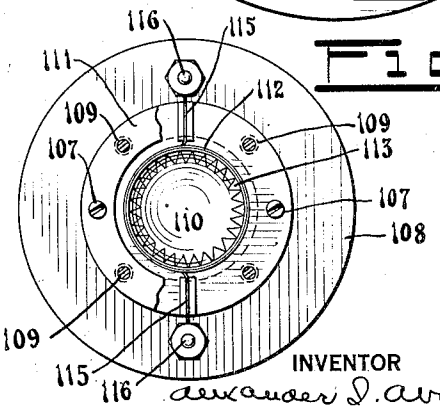


Fig. 13



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UNITED STATES PATENT OFFICE

2,083,537

ELECTROACOUSTICAL TRANSLATING DEVICE

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Application June 13, 1934, Serial No. 730,390

6 Claims. (Cl. 179—115.5)

This invention relates to devices for translating acoustical vibrations into electrical impulses, or conversely for translating electrical impulses into acoustical vibrations.

It relates generally to devices which may be used as microphones in a public address system or radio transmission system or the like, and to devices which may be used as loud speakers in such systems.

More particularly, it relates to apparatus and systems in which a moving diaphragm is used, and in which the motion of this diaphragm is damped by means of suitable chambers, tubes and passages. In the operation of such a device it is necessary for faithful reproduction that the damping shall have the desired effect at all frequencies within any given range.

An object of this invention is to produce a wave translating device having an air damped diaphragm which will respond faithfully to all signals in any given range.

Another object of the invention is to produce a loud speaker device having an air damped diaphragm which will respond faithfully to all frequencies in the audible range.

Other objects of the invention are to provide devices which are cheap to manufacture, have no delicate parts requiring attention, require little skill in assembly, are not affected by weather, temperature, or climate, will stand abuse without getting out of order, and in which the operating parts are protected from injury.

When a horn is used in conjunction with a diaphragm to reproduce the acoustical waves produced by the diaphragm, and the distance between the center of the diaphragm and the opening to the horn is less than the distance between the edges of the diaphragm and the opening to the horn, certain attenuation effects occur at particular frequencies. That is, if the diaphragm is actuated at such a frequency that an acoustical wave produced at the center of the diaphragm reaches the horn opening sufficiently out of phase with a wave produced at the edge portions of the diaphragm, these two waves will tend to neutralize each other and may result in an almost complete attenuation of sound at this particular frequency.

A further object of this invention is to provide a horn loud speaker having an air damped diaphragm in which attenuation effects due to the co-phasic drive of the entire diaphragm are eliminated.

In approaching the problem of suitable damping for a diaphragm when used either in a microphone or loud speaker it is possible to make use of electrical equivalents for the air chambers, tubes and passages provided. This is possible because, as is well known, the characteristics of wave motion are the same for acoustical, mechanical, or electrical systems, and the equations for the propagation, transmission, and dissipation of energy are identical except for the symbols employed. The theory underlying my invention may be explained, therefore, by electrical equivalents.

When a device embodying my invention has its characteristics translated into electrical equivalents it may be seen that these translated characteristics are similar to those of a band pass filter. This is true both of the microphone and the loud speaker disclosed herein.

In the drawings,

Figures 1 to 7 and 15 illustrate my invention when used as a microphone;

Figure 8 shows the approximate electrical system equivalent to the acoustic system of my device; and

Figures 9 to 14 illustrate my invention when used as a loud speaker;

Figure 1 is a side elevation partly in section of my microphone;

Figure 2 is a view along the lines **2—2** of Figure 1 in the direction of the arrows;

Figure 3 is a view along the lines **3—3** of Figure 1 in the direction of the arrows;

Figure 4 is a view along the lines **4—4** of Figure 2 in the direction of the arrows;

Figure 5 is a view along the lines **5—5** of Figure 2 in the direction of the arrows;

Figure 6 is an enlarged view along the lines **6—6** of Figure 5 in the direction of the arrows;

Figure 7 is a view of my diaphragm and the leads connected to the moving coil thereof looking at it from the bottom, or from right to left in Figure 5;

Figure 8 as previously stated is an approximate equivalent electrical circuit diagram of my acoustical damping arrangement;

Figure 9 is a side elevation partly in section of

my loud speaker except that the horn is not shown;

Figure 10 is a plan view of the device of Figure 9, partially broken away, looking from the left;

Figure 11 is a view along the lines 11—11 of Figure 9 looking in the direction of the arrows;

Figure 12 is a view along the lines 12—12 of Figure 9 looking in the direction of the arrows;

Figure 13 is a view of the underside of my diaphragm, that is the side which would be seen if looking from the right in Figure 9;

Figure 14 is a side view of my diaphragm showing the coil secured thereto and the leads from said coil; and

Figure 15 is an enlarged view of a portion of Figure 1.

In Figures 1 to 7 and 15, a casing 21 having threads on its outer surface at one end is adapted to be engaged by a threaded securing member 22. A cover 23, having suitable openings therein to permit acoustical vibrations to reach the diaphragm, is secured to the member 22 by means of screws 24. A pair of spacing rings 25 and 26 are also secured to the member 22 by said screws 24. Another spacing ring 27, which may be of resilient material, engages the spacing ring 25 on its upper surface and the spacing ring 26 at its periphery. A ring of magnetic material 28, which serves as the outer pole piece for the moving coil, is engaged by another spacing ring 29 which may also be of resilient material, and which rests on a flange 30 of the casing 21. The structure comprising the working parts of my microphone is thus securely held in position between the resilient spacing members 27 and 29 for the purpose of separating acoustically the front of the diaphragm from the rear. The ring 28 has apertures therein for the passage therethrough of binding posts 31 which pass therethrough without touching. A second metallic ring 32 of magnetic material is secured to the ring 28 by screws 33 (Figures 3 and 5).

The electrical field for the moving coil is provided by means of four permanent magnets 35 which each have one foot resting on the ring 32 and the other foot resting on magnetic plate 34 yet to be described. The arrangement of these magnets 35 is best shown in Figure 3.

Secured to the outer pole piece 28 by means of screws 36 (Figures 3 and 5) is a damping member 37. The damping member is of non-magnetic material such as aluminum and will be described in detail hereafter. Secured to the damping member by means of screws 40 is a magnet locking member 38 which also is of non-magnetic material and is in the form of a hollow cylinder having a cover at one end, which cover is cut out at its center in the form of a square. The feet of the four magnets which rest on the plate 34 fit tightly inside this square, and may be secured by screws 131 (Figure 3). The magnets establish a magnetic circuit from the plate 34 to the ring 32. The damping member 37 is secured between a T-plate 39 and the plate 34, both of magnetic material, which are held together by screws 132. The plate 39 is the inner pole piece. As shown in Figure 6, pins 41 align the outer pole piece 28 with the damping member 37. Secured to the face of the pole piece 39 by means of a screw 42 is a non-magnetic face plate 43 having a dome shaped surface. A diaphragm 44, which may be of any suitable material such as aluminum or aluminum alloy, is secured between an annular spacer 45 and an annular face member 46 having a tapered edge, by means of screws 47 (Figures 2, 3, 4). The diaphragm is provided with corrugations around its rim as shown to permit it to vibrate, and is held by the members 45 and 46 between washers 48 and 49 (better shown in Figures 4 and 5) which allow sufficient space to permit it to vibrate. Secured to the diaphragm in any suitable manner, as by gluing, and forming an integral part thereof, is an extension 50 to which is fastened a coil of wire 51 having leads 52 connected to the binding posts 31. The members 45 and 46 are further secured together, and to the outer pole piece 28 by means of additional screws 54 (Figure 5).

The damping member 37 may be seen in face view in Figure 6. From Figures 1, 5, 6 and 15 it will be seen that there is an annular groove 55 in the damping member just below the coil 51. This groove provides clearance for the movement of the coil. Extending radially from this groove are radial cuts or slots 56 (Figure 6). The grooves 56 open into an annular air chamber 57, the outer edge of which is formed by the section 58 of the damping member. As the damping member 37 rests squarely against the outer pole piece 28 outside of the coil 51, and against the inner pole piece 39 inside the moving coil, and as the washer 49 makes an air-tight fit with the rim of the diaphragm, the air which is displaced beneath the diaphragm may not escape except through the chambers and passages in the face of the damping member 37. The surfaces 59 of the damping member between the grooves 56 rest flatly against the outer pole piece 28, thus providing closed passages for the air along the grooves. The outer section 58 of the damping member 37, however, is spaced from the face of the outer pole piece 28 a suitable distance to permit air to escape between the two faces. By so proportioning this space it may be caused to act practically as an equivalent electrical resistance. The slots 56 must be so proportioned as to act as an equivalent electrical inductance, and chamber 57 as an equivalent electrical capacity. The air which is released through the space between the outer pole piece 28 and the face of section 58 of damping member 37 escapes inside the casing 21 to the rear of the diaphragm. The space inside the casing 21 about the magnets 35 may be filled or lined with suitable damping material such as felt.

It will be noted that the entire inner structure of my microphone, including the diaphragm assembly, and the damping member which provides the chambers and passages, and the inner pole piece are all supported by the outer pole piece.

The electrical circuit equivalent of the diaphragm and damping arrangement of my microphone is shown in Figure 8. In this figure m_1 represents the inductance due to the mass of the diaphragm and c_1 represents the reciprocal of the stiffness of the diaphragm. c_2 represents the reciprocal of the stiffness of the air chamber under the diaphragm plus one half of the reciprocal of the stiffness of the air in the slots. m_2 represents the inductance due to the mass of air in the passages or slots 56 connecting the chamber under the diaphragm with the chamber 57. c_3 represents the reciprocal of the stiffness of the chamber 57 plus one half of the reciprocal of the stiffness of the air in the slots, and R represents the resistance due to the passage of air between the outer pole piece 28 and the face 58 of the damping member. The reason air

spaces have the equivalent effect of inductance, capacity and resistance in different cases is well known, and is due to the relative configuration of the space through which the air is being transmitted. Thus the chamber under the diaphragm and chamber **57** act as capacities because of their relatively large dimensions transverse to the direction of motion as compared to their dimensions in the direction of motion. The passages or slots **56** act as inductances in parallel with capacities because of their relative dimensions and the pasage between pole piece **28** and surface **58** acts as a resistance because of the relatively small depth transverse to the direction of motion as compared to the width transverse to the direction of motion.

In Figures 9 to 14 my invention is illustrated in the form of a loud speaker. In these figures a cover **101** of magnetic material has a central pole piece **102** secured thereto. A coil **103** provides the field. An outer pole piece **104** of magnetic material is secured to the cover **101** by means of screws **105**. A metallic member **108** of non-magnetic material such as aluminum is secured to the outer pole piece **104** by means of screws **109**. A diaphragm **110** is secured at its outer rim to the member **108** by means of screws not shown, and is spaced from the member **108** and the outer pole piece **104** by means of washers **111** and **112**. The washer or washers are of non-magnetic material. The diaphragm has a portion **113** which is secured thereto by gluing or other suitable means, or is integral therewith, and on which is wound a coil **114**, having leads **115** connecting it to binding posts **116**. A horn supporting member **118** is secured to member **108** by means of screws **119**. The member **118** is hollowed at one end to provide an air chamber **120** between its under surface and the upper surface of member **108**. The member **118** also has a central bore **121** to permit the release of air to the horn. The member **108** has a plurality of tubes **122** (Figures 9, 10, 12) therethrough for a purpose to be described. These tubes open at one end into the air space above the diaphragm and at the other end into the air chamber **120**.

The signal currents which are to be translated into acoustical vibrations are, of course, applied to the coil **114** through the leads connected to binding posts **116**. When such signals are applied the diaphragm is driven in response thereto.

When the diaphragm chamber leads directly into the horn through a central opening, if the distance between the center of the diaphragm and the opening to the horn is less than the distance betwen the edge of the diaphragm and the opening to the horn it is possible, as previously explained, that certain attenuation effects will be present due to the co-phasic drive of the diaphragm. In order to eliminate these effects the tubes **122** which lead from the diaphragm to the horn are displaced from the center of the diaphragm. These tubes are located at such a point that the volume of air displaced between the surface of the diaphragm and the surface of member **108** facing the diaphragm may be divided into two equal portions on both sides of these tubes. One portion is that above the central portion of the diaphragm bounded by the tubes **122** and the other portion is the remainder of the space outside the tubes between the tubes **122** and the edge of the effective diaphragm. In other words, calling the radius of the total effective area of the diaphragm R, and the radius of the section inside the tubes r', the volume of the space above the diaphragm bounded by the tubes will be $\pi r'^2 l$ and the volume of the space above the diaphragm outside the tubes will be $(\pi R^2 - \pi r'^2) l$ where l is the distance between the diaphragm and the concave surface of the member **108**. The condition desired, then, is that $\pi r'^2 l = (\pi R^2 - \pi r'^2) l$. Solving this equation

$$r' = \frac{R}{\sqrt{2}} \text{ or } .707\ R.$$

In other words, the radial distance of the tubes **122** from the center of the diaphragm is approximately seven tenths the distance from the center of the diaphragm to the effective edge of the diaphragm. The effective edge of the diaphragm is the edge of a piston diaphragm equivalent to the diaphragm in the device. This distance is not extremely critical and the spacing of these tubes may be varied slightly without serious results.

The diaphragm is controlled in its movement by the mass, elasticity and viscosity of the air in the chambers and slots above it. As in the case of the microphone previously described the arrangement is such that it is equivalent to a band pass filter for all the frequencies in the audible range. The circuit diagram of Figure 8 may again be used in explaning the operation of the apparatus just described in controlling the action of the diaphragm, as it was used in describing such action in connection with the microphone. Here again m_1 represents the mass of the diaphragm, c_1 the reciprocal of the stiffness of the diaphragm, c_2 the reciprocal of the stiffness of the air chamber above the diaphragm plus one half of the reciprocal of the stiffness of the air in the slots, m_2 represents the inductance due to the mass of air in the tubes **122** connecting the chamber above the diaphragm to the chamber **120** leading to the horn opening, c_3 represents the reciprocal of the stiffness of chamber **120** plus one half of the reciprocal of the stiffness of the air in the slots, and R represents the resistance of the air in the horn. As is well known, the air in an exponential horn is properly represented as a pure resistance.

In the construction of my microphone and loud speaker in the manner described it is possible to attain extreme accuracy. No washers are used to provide the spacing for the air chambers and the passages, and these may be properly made by accurate machine work. The assembly is simple and all centering may be taken care of by pins. It is thus possible for my microphone or loud speaker unit to be properly assembled by unskilled workmen, as no precise adjustments of any kind are required, these being taken care of in the machining.

What is claimed is:

1. A loud speaker unit comprising a diaphragm, inner and outer pole pieces for said diaphragm, a member forming an air space above said diaphragm, a plurality of slots or tubes in said member, means comprising an air chamber into which said slots or tubes release, a horn, and means for releasing air from said chamber to said horn.

2. A loud speaker unit comprising a moving coil diaphragm, inner and outer pole pieces for said diaphragm, a coil for establishing a magnetic circuit between said pole pieces, a member having a concave central section adapted to form an air chamber above said diaphragm, a plurality of holes in said member, an air chamber into which said holes release, and a horn communicating with said air chamber.

3. A loud speaker unit comprising a diaphragm,

a member adapted to form an air space between its surface and the surface of the diaphragm, a plurality of holes arranged symmetrically about the center in said member, the average distance of said holes to the center of said diaphragm in a plane transverse to the movement of said diaphragm being approximately seven-tenths the radius of the effective area of said diaphragm.

4. A wave translating device comprising a vibratory diaphragm, a sound chamber at one side of said diaphragm, means dividing said chamber into two compartments, acoustic conduits connecting said compartments, said conduits being positioned with respect to the center of said diaphragm so that attenuation effects due to co-phasic drive of the diaphragm will be substantially eliminated.

5. A wave translating device according to claim 4 in which the said conduits are symmetrically disposed with relation to the center of the effective area of the diaphragm.

6. A wave translating device according to claim 4 in which the ratio of the average distances of said conduits from the center of the effective area of said diaphragm to the average diameter of the effective area of said diaphragm is approximately seven to ten.

ALEXANDER I. ABRAHAMS.