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C. A. LOVELL ET AL

2,079,694

ACOUSTIC AMPLIFIER

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FIG. 2

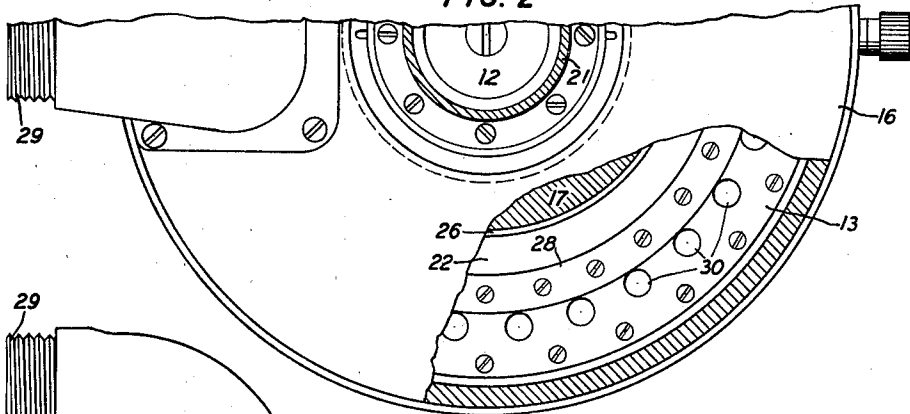


FIG. 1

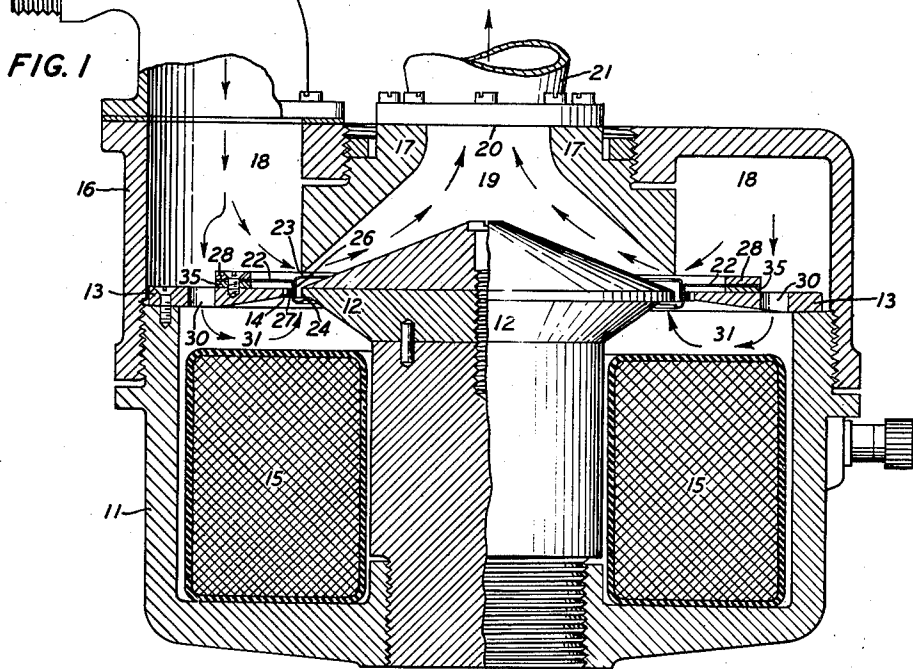
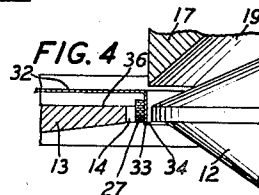
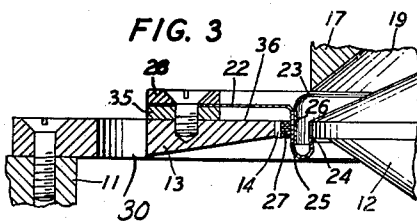


FIG. 3



INVENTORS: C. A. LOVELL
R. L. WEGEL

BY

G. M. Pampall

ATTORNEY

UNITED STATES PATENT OFFICE

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ACOUSTIC AMPLIFIER

Clarence A. Lovell and Raymond L. Wegel, New York, N. Y., assignors to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

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11 Claims. (Cl. 179-108)

This invention relates to acoustic amplifiers and more particularly to devices of this type in which a vibrating valve modulates a fluid stream at an orifice to produce large volumes of sound.

Devices of this type have been proposed heretofore but these prior structures have, in general been unsatisfactory for several reasons. The high fluid pressures necessary for large sound outputs subjected the modulating member to such high stresses, static and vibratory, that the vibratory parts were necessarily very heavy and rugged in construction and hence unable to respond uniformly over the required range of frequencies. The sound output of these prior amplifiers was also usually of very inferior quality and in amplifiers of large capacity it was often almost unintelligible.

The object of this invention is an acoustic amplifier capable of large sound output at high efficiency and with much better quality than can be obtained with structures of prior designs.

In accordance with the general features of the invention, the operation of these devices is stabilized by the control or elimination of the reaction of various types of the air or other fluid on the modulating valve. This is accomplished by balancing the static and vibratory forces acting on opposite sides of the valve and reducing to a minimum the gyrostatic feed-back by making the mutual area between the modulator and the orifice as small as possible.

In the preferred structure, according to the invention, the modulating valve is a thin lightweight annular diaphragm having a cylindrical portion supporting, in the air-gap of a magnetic circuit, a coil for driving the diaphragm and joining the annular portion in a well-defined edge which forms one side of an annular orifice in the fluid conduit conducting the stream to be modulated. The other side of the orifice is defined by the directly opposed edge of an annular piece enclosing a sound chamber having an outlet to which a suitable sound radiating horn may be attached.

The fluid stream in passing through the orifice to the sound outlet chamber exerts a static pressure on the diaphragm but fluid passages to the other side of the diaphragm of sufficient size and number are provided to maintain the static pressures on the opposite sides of the diaphragm equal under all operating conditions.

In one embodiment of the invention, the cylindrical portion of the diaphragm is turned up to define a second orifice with the edge of the central pole-piece of the magnetic circuit in such a

way that the diaphragm vibrations vary the areas of the two orifices simultaneously in the same manner. The portions of the diaphragm adjacent the orifices and exposed to the alternating pressures in this construction are so proportioned that the reactions of these pressure variations on the two portions of the diaphragm oppose and neutralize each other.

The expression gyrostatic feed-back used above refers to the reaction on the modulator as it varies the orifice area due to the change in kinetic energy of the mass of air passing between the surfaces defining the orifice. The magnitude of this force can be shown to be given by the differential

$$\frac{d(1/2 M \dot{x}^2)}{dx}$$

in which M is the mass of air between the surfaces defining the orifice, $\dot{x}$ is the velocity of the air flow and dx is the change in x the variable orifice dimension. In order to stabilize the operation of the device this reaction should be made as small as possible. This is accomplished in the structures shown by making the orifices substantially knife-edged so that the mass of air within the orifice is a minimum.

In an alternate construction only the single orifice first described is used, the normally fixed edge of the orifice being directly above the cylindrical portion of the diaphragm so that the areas of the two sides of the diaphragm exposed to the static pressure are equal. By leaving the inner edge of the diaphragm free and providing a small leakage path through the air-gap to the sound outlet chamber, the diaphragm of this device can be kept in balance for both static and alternating pressures and the device can be operated at substantially the same efficiency as the two orifice construction as explained more fully below.

These and other features of the invention will be more clearly understood from the following detailed description and the accompanying drawing, in which:

Fig. 1 is a sectional view of an acoustic amplifier according to the invention;

Fig. 2 is a plan view of the amplifier with portions broken away to show the internal construction;

Fig. 3 is an enlarged sectional view of the modulator of a double orifice amplifier; and

Fig. 4 is an enlarged sectional view of the modulator of a single orifice amplifier.

In Fig. 1, the magnetic portion 11 of the hous-

ing is fitted with a central pole-piece 12 and an annular plate 13 which define a circular air-gap 14 across which flows the flux set up by the field coil 15. The non-magnetic part 16 of the housing is fitted with an annular center member 17 which divides this portion of the device into an outer inlet chamber 18 and a central outlet chamber 19 having a sound opening 20 leading into the throat of a suitable exponential horn 21.

The valve or modulator consists of a thin annular diaphragm 22 of strong light metal which in conjunction with the member 17 and the pole-piece 12 defines two orifices 23 and 24. As shown more clearly in Fig. 3, the diaphragm has a cylindrical portion 25 turned up to form the orifice 24 and a second similar cylindrical piece 26 is cemented to the first to form the orifice 23. The driving coil 27 is cemented to and held in the air-gap by the diaphragm which is clamped to the pole-piece 13 by a clamping ring 28. The washer 35 holds the diaphragm above the face 36 of the pole-piece with vibrating clearance and the pressures on the upper side of the diaphragm are balanced by equal pressures transmitted through the air-gap 14 to the air within this space. Since the member 17 and the pole-piece 12 are both threaded into the housing, the area of each orifice may be adjusted independently of the other.

The structure shown is intended to be operated by compressed air which is supplied to the chamber 18 under from 14 to 23 lbs. per square inch gauge pressure through the inlet 29. From this chamber, part of the air flows through the holes 30 in the pole-piece 13 into the chamber 31 and through the orifice 24 to the outlet chamber 19. The remainder of the air passes directly through the orifice 23 to the chamber 19 and the combined orifice discharges then pass outward through the horn 21. The total area of the holes 30 is made large enough to keep the steady pressure in chamber 31 the same as that in chamber 18 so that the static force on the lower side of the diaphragm balances out the force on the upper side and the diaphragm is not deflected from its normal position.

When the diaphragm moves upwardly under the influence of signal currents in the coil 27, the areas of both orifices are decreased and the flow through the horn is correspondingly decreased and when the diaphragm moves downwardly the areas of the orifices are increased and the air flow is increased. When these motions occur at audible frequencies, high alternating pressures are generated in the chamber 19 and sound waves of great intensity are radiated from the horn.

These large alternating pressures on the downstream sides of the orifices have no effect on the diaphragm vibrations since the projections of the curved portions of the cylinders 25 and 26 on the plane of the diaphragm are equal and the alternating forces on these areas are in opposite directions.

If the velocity of the air through the orifices is equal to or greater than the velocity of sound the alternating pressures are not transmitted upstream from the orifices and hence have no effect on the flat portion of the diaphragm. If the velocity at the orifices is less than that of sound the alternating pressures are transmitted upstream but the magnitude of these forces on the flat portion of the diaphragm is relatively small due to the low acoustic impedance of the chambers 18 and 31 and in any case they react

equally in opposite directions on the upper and lower sides of the diaphragm.

It will be noted that the orifices 23 and 24 are defined by the thin edges of the cylindrical portions 25 and 26 of the diaphragm and the sharp corners of the members 17 and the pole-piece 12 so that the volume of air actually within the orifices is very small and the gyrostatic feedback effect discussed above is therefore very small.

In the alternate modulator construction shown in Fig. 4, the single orifice is defined by the sharp edge of the member 17 and the sharp corner between the cylindrical part 32 and the flat portion of the diaphragm.

It might be thought desirable from the standpoint of efficiency to secure the diaphragm to the underside of the pole-piece 12 by a second clamping ring in which case the whole air stream would be modulated in passing through the orifice. With that construction however the portion of the diaphragm necessary to close the air-gap completely would be subjected to the high static pressure of the chamber 31 on the lower side with no corresponding static pressure on the upper side. The upper side would be subjected to the alternating pressures in the chamber 19 which would not act on the lower side of this area. The diaphragm of such a device would therefore be unbalanced for both static and alternating pressures. This is avoided in the construction shown by using a diaphragm consisting merely of a flat portion 32 and a straight cylindrical portion 33 and leaving a leakage path 34 between the chambers 31 and 19 that is between the upstream and downstream sides of the orifice. With this construction both the steady and alternating pressures are effective on equal areas on opposite sides of the diaphragm so that a practically perfect balance can be obtained.

It will be understood of course that the radial pressures on the cylindrical portion of the diaphragm in both this construction and that of Fig. 3 are not balanced. The static pressure of chamber 31 all around the cylinder is toward the pole-piece 12 and is opposed only by the alternating pressures within the cylinder but even very thin cylinders are capable of withstanding these radial stresses and the unbalanced components are normal to the direction of diaphragm motion and hence have no substantial effect on the operation of the device.

In order to keep distortion in the sound output within satisfactory limits, the percentage of modulation must be appreciably less than 100 per cent in any case and hence the conversion efficiency of the single orifice construction can be made to approach that of the double orifice design.

In applying the principles of the invention to a specific structure, it is found that the best ratio of total orifice area to the area of the opening at the horn throat varies with a number of factors among the more important of which are the operating pressure and the amount of distortion to be tolerated in the sound emitted. In any case the orifice must control the flow of air through the device and hence the area of the sound opening must be larger than the area of the orifices so that the greater part of the pressure drop occurs at the orifice.

For maximum efficiency the sound opening should be as small as is consistent with the requirement that the orifice shall control the flow but in some cases such a small opening results in such high alternating pressures that distortion

takes place in the horn itself. For this reason a compromise is necessary between efficiency and quality of reproduction and the sound opening is therefore made large enough to keep the distortion within the desired limits. When efficiency is the most important consideration, the opening may be only three times or even only twice the total orifice area but for good quality transmission of speech, a ratio of about six is usually satisfactory.

What is claimed is:

1. In an acoustic amplifier, a conduit for a fluid stream, a valve in the conduit, means for vibrating the valve to modulate the fluid stream, and means for equalizing the static reactions of the fluid on opposite sides of the valve, and means wholly within the amplifier on the down stream side of the valve for keeping the valve in balance for alternating pressures of the modulated stream.

2. In an acoustic amplifier, a conduit for a fluid stream, an annular valve mounted at its periphery in the conduit with one side exposed to the fluid stream and forming an orifice therefor, means for vibrating the valve to modulate the stream at the orifice, a chamber on the other side of the valve, and an air path between the chamber and the conduit adjacent the exposed side of the valve, the area of the path being large as compared with the area of the orifice to maintain the static pressures on the opposite sides of the valve equal.

3. In an acoustic amplifier, a source of fluid under pressure, two fluid inlet chambers, an outlet chamber, a vibratile member between the inlet chambers defining an orifice between each of the inlet chambers and the outlet chamber, means for driving the member to vary the areas of the orifices, and means for adjusting the area of each of the orifices.

4. In an acoustic amplifier, a magnetic circuit including a central pole-piece and an annular pole-piece defining an air-gap, a coil for signal currents disposed in the gap, an annular diaphragm supporting the coil, a central outlet chamber having a sound radiating opening, means for impressing equal fluid pressures on opposite sides of the diaphragm, a substantially knife-edged orifice in the chamber on one side of the diaphragm, and a fluid path from the other side of the diaphragm through the central opening thereof to the outlet chamber.

5. In an acoustic amplifier a conduit for an air stream, a valve defining an orifice in the stream, a magnetic circuit including a gap, a coil in the gap for vibrating the valve and a leakage path of substantially constant area through the air-gap between the upstream and downstream sides of the orifice.

6. A modulator for an acoustic amplifier comprising an annular diaphragm, a coil mounted on the diaphragm and a curved extension piece having a modulating edge on each side of the diaphragm, said extension pieces having substan-

tially equal projections on the plane of the diaphragm.

7. In an acoustic amplifier, the combination with an air inlet chamber, a sound outlet chamber and a diaphragm, of two air paths between said chambers on opposite sides of the diaphragm, means for vibrating the diaphragm and means on the diaphragm defining an orifice in each of the paths, the surfaces of the orifice defining means which are in the outlet chamber being proportioned to have equal projections on the plane of the diaphragm.

8. In an acoustic amplifier, a conduit for an air stream, a vibrating valve exposed on both sides to the static pressure of the air stream and defining an orifice on one side of the valve varying in area in accordance with the vibrations of the valve and a leakage path of substantially constant area between the other side of the valve and the conduits on the downstream side of the orifice.

9. In an acoustic amplifier, the combination with an air stream and a magnetic circuit including a pair of concentric pole-pieces defining an air-gap, of a modulator comprising a coil and a diaphragm having a flat annular portion exposed on both sides to the pressure of the air stream and a cylindrical portion open at both ends supporting the coil in the air-gap and joining the flat portion in a well defined modulating edge, and a member in the conduit having a normally fixed edge aligned with the cylindrical portion of the diaphragm.

10. In an acoustic amplifier, a casing, a magnetic circuit within the casing having a central pole-piece and an annular pole-piece defining a gap, means for producing equal static air pressures on opposite sides of the annular pole-piece, an annular member, a central sound outlet chamber defined by said member and the central pole-piece and means for modulating the flow of air into the outlet chamber comprising a signal coil in the air-gap and an annular diaphragm supporting the coil and having means defining an orifice for the discharge of air into the outlet chamber.

11. In an acoustic amplifier, a casing, a magnetic circuit within the casing having a central pole-piece and an annular pole-piece defining a gap, an annular member defining a central sound outlet chamber, means for producing equal static air pressures on opposite sides of the annular pole-piece, an air path from one side of the annular pole-piece to the outlet chamber, a second air path from the other side of the pole-piece through the air-gap to the outlet chamber and means for modulating the flow of air in said paths comprising a signal coil in the air-gap and an annular diaphragm supporting the coil and defining orifices in the paths varying in area in accordance with the vibrations of the diaphragm.

CLARENCE A. LOVELL.
RAYMOND L. WEGEL.