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PATENT SPECIFICATION

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COMPLETE SPECIFICATION

Improvements in Electro-acoustic Devices

We, ALAN DOWER BLUMLEIN, British subject, of 57, Earl's Court Square, London, S.W.5, and HERBERT EDWARD HOLMAN, British Subject of 64A, The Chase, Clapham Common, London, S.W.4, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:-

This invention relates to electro-acoustic devices employed for the inter-conversion of acoustic and electrical vibrations, such as microphones, loudspeakers and the like, and is especially directed to microphonic apparatus of this type intended for use with the sound recording apparatus described in our Patent Specifications Nos 350,954 and 350,998.

The invention consists I an electro-acoustic device having a vibrating system comprising a substantially rigid piston-like diaphragm connected at its outer edge to a flexible air sealing surround wherein means are provided for damping resonate vibrations of the said surround which means may also shield the surround.

The invention further consists in an electro-acoustic device as set forth above wherein the piston-like portion of the diaphragm is composed of light wood, such as Balsa wood, covered on either side or on both sides by a thin plate of aluminium or other light metal or alloy.

The invention also consists in an electro-acoustic device as set for the above wherein the main resonance of the device is controlled by electromagnetic damping.

The invention also consists in an electro-acoustic device as set forth above wherein a coil is adapted to move in a magnetic field.

Further features of the invention will appear from the following description of one embodiment thereof which will be more readily understood by reference to the accompanying drawing representing a longitudinal section through the axis of a microphone constructed in accordance with the invention.

The principles upon which the invention is based will be set for the by consideration of a microphone consisting of a piston-like diaphragm caused to move by sound waves impinging thereupon. In order that this diaphragm shall be free from resonances due to its own flexure it is desirable to make it rigid. Also, it is desirable that the mass of the diaphragm be as low as

possible in order that it shall respond amply to the high frequency sound waves incident on it. One object of the present invention is to make a diaphragm which will meet the conflicting requirements of great rigidity and low mass, and this object is met if the diaphragm is made of a three-ply construction, consisting of two thin layers of a light metal such as aluminium enclosing a centre of light wood such as Balsa wood.

If air is permitted to pass freely from the front to the back of such a diaphragm, the response of the device at all low frequencies will be impaired due to the diaphragm receiving almost equal variations of sound pressure on both its front and back faces. Therefore it is necessary to provide a closed cavity (or baffle) containing (or shielding) the air behind the diaphragm and to supply an air seal between the sides of the diaphragm and the sides of the air cavity. Such a seal for a microphone cannot in practice take the form of a frictional packing on account of the delicate nature of the movements of the diaphragm; and therefore a thin elastic surround is provided between the diaphragm and the sides of the cavity. The diaphragm then forms a rigid piston closing the mount of a closed cavity, the edge of the diaphragm being sealed by a thin surround which stops the direct access of air to the cavity, but nevertheless permits the diaphragm to move. The surround which forms the air seal may conveniently support the diaphragm.

According to one embodiment of the invention the diaphragm has attached to its rear surface (i.e. the surface within the cavity and not exposed directly to incident sound waves) a coil which can move freely in a magnetic field provided by an electromagnet or permanent magnet. This coil serves to convert the mechanical movement of the diaphragm into electric impulses and may also be utilised to provide damping for the resonance of the mass of the diaphragm and its elastic constraints. Such damping may be provided by connecting the moving coil to a circuit having a low impedance at frequencies close to the resonance of the oscillating mechanical system by which means an e.m.f. generated by the moving coil will cause damping current to flow through the moving coil. It is thus possible to control the main resonance of the microphone and make the response such that it may be easily equalised by suitable electrical circuits. In order that this resonance may be well controlled, it is convenient to make the main resonant frequency as lows as possible, and in order to do this it is necessary to make the surround thin and flexible. Such a thin flexible surround is liable itself to resonate due to high frequency sound waves impinging on it; the resonance being due to the mass of the surround (and coupled air mass) resonating with the stiffness of the surround (and coupled air stiffness). At the frequency of this resonance the mass reactance of the piston diaphragm is so high that it acts almost as a rigid support to the inner edge of the surround; but nevertheless, a violent resonance of the surround is sufficient to modify the movement of the piston diaphragm and so modify the response of the microphone.

A further object of the invention is to reduce or prevent the resonance of the surround so that the response of the microphone is controlled and regular at high frequencies, and in order to do this the surround may be shielded from direct access of high frequency waves by means of a shield positioned close to the surround in front of it. Further the surround may be provided with damping in order to damp its resonance, since if its resonance is well damped it will be unable to affect appreciably the movement of the cooperatively heavy piston diaphragm. Such damping may take the form of a ridge member fixed to the body of the microphone and extending over the surface of the surround, and ver close to it, thus providing viscosity damping due to the thin film of air trapped between the surround and the fixed member.

Such damping must not be confused with damping applied to control the main resonance of the microphone. The degree of damping necessary to control the resonance of the thin light surround is much smaller than that necessary to control the main resonance of the microphone. Further, the value for the damping applied to the surround has no very critical effect upon the response of the microphone, provided that this damping is sufficient to reduce materially the effects of the surround resonance on the movement of the piston diaphragm. Were an attempt made to control the main resonance by means of this damping, the response of the microphone at its main resonance would depend entirely on the damping provided; and also, with the degree of viscosity damping easily obtainable, the resonance peak would be very sharp and difficult to equalise.

Hence according to the invention a piston-like diaphragm is used, sealed in the mouth of a cavity by a thin flexible surround, which surround may also serve to support the diaphragm. The main resonance of the mass of the piston diaphragm (and anything attached to it such as a moving coil) with its elastic constraint is controlled by special damping such as electromagnetic damping. The resonance or resonances of the thin surround are prevented and/or controlled by special shields interposed to prevent the incidence of direct H.F. waves on the surround and by special damping applied specifically to the surround. Such shielding may take the form of a member extending over the front of the surround and close to it. The damping for the surround may take the form of a member lying ver close to either the front or back of the surround and thus damping it due to the viscosity of the trapped air. Alternatively members may be placed both in front of and behind it so as to damp it more effectively or a packing of cotton wool or other damping material may rest lightly against the surround. In order that the thin surround may be flat it is desirable to arrange that it is suitably stretched when in position. By varying the amount of stretch a useful control of the main resonate frequency may be obtained.

The figure attached shows a section through the axis of a microphone according to this invention constructed in accordance with the above principles.

The diaphragm comprises a layer of Balsa wood a^1 covered on each side by a thin sheet of aluminium, b^1, pressed and waxed together to form a rigid structure. Alternatively the diaphragm may be formed only of Balsa wood or other wood, allowing a highly rigid light diaphragm to be constructed; or it may be built up from a flat diaphragm of aluminium or other light alloy with cones of similar material attached to the back in order to brace the diaphragm to rigidity. The support may consist of a light elastic connection at the edges of the diaphragm and in the form shown consists of an extended annulus c^1 of the back aluminium covering sheet. This sheet is pressed into the dish-shaped form shown I order that the plane of support by the annulus c^1 may pass through the centre of gravity of the system supported. For increased flexibility the annulus c^1 may be much thinner than the plate proper, this thinning being accomplished for example, after the plates are fixed to the wood, by dissolving off some of the metal with caustic soda.

To the back of the diaphragm may be attached a coil d^1 formed of thin enamelled aluminium wire wound on a thin aluminium former e^1 which may be fixed to the diaphragm by rivets f^1. In order to avoid short circuited turns the coil former may have in it a longitudinal saw cut extending almost to the diaphragm and may, before use, be insulated by a coating of aluminium hydroxide.

Conveniently the microphone may be more or less bottle-shaped (as shown) with a maximum diameter of say, 3 inches, the body and neck of the bottle forming the magnetic system, while an attached holder, g^1, for the diaphragm and moving coil, forms the bottom of the bottle. This holder g^1 may be fitted to the outer pole piece h^1 of a small pot magnet by three, or more, centering screws *I*; and the diaphragm and moving coil secured against a step j^1 of the holder, between washers k^1, by means of a screw threaded clamping ring l^1. Held by screw threads tapped within the clamping ring l^1 is a diaphragm stretching ring m^1 which, on being screwed inwards, brings a small round ridge n^1 to bear against the annulus c^1 (which on account of its frailty and flabbiness tends to become wrinkled and distorted) thereby stretching it smooth and taut. As a matter of little importance it is to be noted that by means of this stretching ring a degree of control on the natural frequency of the diaphragm is also available.

As well as carrying the rounded ridge n^1, the stretching member forms a shield over the thin surround, and to some extent serves to damp resonances in the surround. It will be seen from the drawing that the stretching ring has a portion which passes very close to the surround and lies close to the sloping sides of the piston portion. This shield serves, as explained, to reduce or prevent resonances in the surround. Increased damping on the surround can be obtained by making a small cavity between the stretching ridge n^1 and the smooth portion of the shielding and damping surface; such a cavity may consist of a groove in the stretching ring immediately inside the stretching ring immediately inside the stretching ridge n^1 and such a groove may be say 1 mm. deep and 1 mm. broad. By making the damping surface lie very close indeed to the surround, at a point just adjacent to this groove, it can be arranged that the damping is increased due to small movements of the surround forcing air into the groove through this narrow neck between the damping surface and the surround. These effects may be enhanced by fitting another damping surface close to the surround at the back of the diaphragm.

To protect the diaphragm from accidental damage the aperture in the ridge m^1 through which the sound waves proceed may be formed only of a number of small holes o^1 drilled through the plate thus forming a grille which seems not to affect the acoustic properties of the device although serving admirably for protection.

The magnetic circuit as previously mentioned comprises a small pot magnet, and is formed of an outer pole piece h^1, the case of the microphone p^1, a rear plate, q^1, and a center pole piece r^1, on which are mounted the windings s^1. Between the inner and outer poles is a gap (which is shown excessively large in the drawing for convenience of illustration) in which the moving coil is positioned, and in order that the dimensions of this gap shall be correct a spacing ring t^1 of brass or, preferably, cadmium bronze, may be provided. This may be a force fit on the inner pole piece and a good fit in a groove in the outer pole piece and serves not only to space the poles correctly but also to reduce the inductance of the moving coil, being magnetically coupled with it and having a low resistance.

The inner pole piece is preferably made of cobalt iron or other material having a high saturation density; but the flux density in the other portions of the circuit maybe kept quite low, and good magnetic iron of thickness sufficient for the strength required may conveniently be used. The windings s^1 fill the body of the microphone between the pole pieces, and are preferably formed of two different gauges of wire, the inner turns being of thinner gauge than the outer.

In order to avoid undue elastic restraint on the diaphragm by the air between it and the poles of the magnet if is desirable that a reasonably large volume be enclosed. To this end a cavity u^1 is provided between the holder g^1 and the outer pole piece h^1; and communicating with the rear of the diaphragm by an annular passage v^1, in which may be inserted a ring of loose cotton wool w^1 to damp resonance between the mass of air in the passage and the stiffness of the air in the main cavity. To avoid restraint due to air trapped within the moving coil former between the diaphragm and the inner pole piece holes may be drilled in the former as shown. Further to allow variations of the steady atmospheric pressure (as distinct from rapid periodic sound-wave variations) to be equalised on both sides of the diaphragm air leaks such as capillary tunnels may be provided leading to the cavity behind the diaphragm. The leads from the moving coil as shown pass through the annular passage and cavity to terminals on the holder g^1 but if desired the terminals may be located at any other suitable position such for example as at the rear end of the microphone.

The moving coil may be shunted by a circuit which in its simplest form consist of an inductance resistance and condenser in series, which circuit is designed to have a low impedance at frequencies close to resonance but a high impedance at frequencies remote from resonance, so that damping is provided electromagnetically but the efficiency of the device is not impaired at those frequencies where it is least efficient. Similarly other circuits may be used for this purpose as described in our Patent Specification Nos 350,954 and 350,998.

Should it be desired to form a loud-speaker in accordance with this invention, this may be done with a construction very similar to that shown for the microphone, except that a horn or baffle may be fitted at the mount in front of the diaphragm. The shield on the surround then prevents the surround generating an excess of high frequency waves when it resonates.

It must be understood that prior proposals have been made to shield the flexible support of a diaphragm from damage and from directly incident vibrations, but in these known devices considerable clearance between the shield and the support has been left and thus no damping has been effected by the shield. The primary purpose of the device described herein is to damp parasitic vibrations of the flexible support and no claim is made to shielding of the support as such, except insofar as the damping member may also act as a shield.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is:-

1. An electro-magnetic device having a vibrating system comprising a substantially rigid piston — like diaphragm connected at its outer edge to a flexible air sealing surround wherein means are provided for damping resonant vibrations of the said surround which means may also shield the surround.
2. An electro-acoustic device as claimed in Claim 1 wherein the air sealing surround also supports the diaphragm.
3. An electro-acoustic device according to Claim 1 or 2 wherein the diaphragm and its surround close the mount of a closed cavity.
4. An electro-acoustic device as claimed in Claim 3 wherein air leaks are provided sufficient to equalise the steady atmospheric pressure but not admit sound waves.
5. An electro-acoustic device as claimed in Claim 3 or 4 wherein cotton wool or other damping material is placed in the cavity in order to damp acoustic resonances within the cavity.

6. An electro-acoustic device as claimed in any of Claims 1 — 5 wherein the diaphragm and surround are mounted in an opening in a baffle.
7. An electro-acoustic device according to any of the preceding claims wherein the piston-like portion of the diaphragm is composed of light wood, such as Balsa wood, covered on either side or on both sides by a thin plate of aluminium or other light metal or alloy.
8. An electro-acoustic device as claimed in Claim 7 where air sealing surround comprises an annulus of aluminium or other metal forming part of the piston-like portion, which annulus may be suitably thinned, e.g. by chemical means, for increased flexibility.
9. An electro-acoustic device according to any of the preceding claims in which the surround is clamped at its perimeter to a rigid holder.
10. An electro-acoustic device according to any of the preceding claims provided with means whereby the smoothness and/or the tension of the surround may be adjusted.
11. An electro-acoustic device as claimed in Claim 10 in which the said means comprise a stretching ring provided with a projection, such as a smooth circular ridge, adapted to be pressed against the surround just within the clamping means.
12. An electro-acoustic device according to any of the preceding claims wherein an annular member or members are adapted to lie very close to the surround for the purpose of controlling subsidiary resonances.
13. As electro-acoustic device as claimed in Claim 12 wherein the separation between the annular member or members and the surround is reduced towards the perimeter of the surround.
14. An electro-acoustic device as claimed in Claim 12 or 13 wherein annular grooves are cut in the annular member or members in the surface adjacent to the surround.
15. An electro-acoustic device as claimed in Claim 12, 13 or 14 in which the annular member of members approach the surround over at least one third its area to a distance not greater than one tenths of a millimeter.
16. A microphone according to any of the preceding claims, provided with a shield adapted to prevent direct incidence of sound on the surround, which shield may be one of the annular members specified in Claim 12, 13, 14 or 15.
17. An electro-acoustic device according to any of the preceding claims I which a pad of cotton wool or other suitable material is adapted to rest lightly against the surround for the purposes specified.
18. An electro-acoustic device according to any of the preceding claims wherein the main resonance of the device is controlled by electromagnetic damping.
19. An electro-acoustic device according to any of the preceding claims wherein a coil is adapted to move in a magnetic field.
20. An electro-acoustic device as claimed in Claim 19 wherein the moving coil is connected to a circuit whose impedance is low at frequencies close to the main resonant frequency.
21. An elector-acoustic device as claimed in Claim 20 in which the impedance of the closing circuit increases at frequencies remote from resonance.
22. An electro-acoustic device as claimed in any of Claims 18 — 21 wherein the electromagnetic damping circuit is also employed to equalise or modify the characteristic response of the vibrating system.
23. An electro acoustic device according to any preceding claim wherein to prevent accidental blows or like damage to the diaphragm, access thereto may only be had through a plurality of small holes bored in the grill formation in the aforementioned shielding pate; or through a larger aperture protected by a grid of bars or the like.

24. An electro-magnetic device according to any preceding claim in which a coil of thin enamelled aluminium wire or other suitable material is attached to the rear side of the diaphragm such as by means of a former (preferably comprising a light cylinder of aluminium or other suitable metal or alloy coaxial with the diaphragm) on which the coil is wound.
25. An electro-acoustic device according to Claim 24, wherein the former supporting the coil is attached to the diaphragm by means of rivets through an out-turned annular lip at one end; and to prevent short circuited turns in the field the former may have a longitudinal saw cut extending almost over its whole length and may be insulated, e.g. by a coating of aluminium hydroxide.
26. An electro-acoustic device according to any preceding claim wherein the support of the moving system (comprising diaphragm, coil, former, etc.) is co-planar with the centre of gravity thereof.
27. An electro-acoustic device according to Claim 26 wherein he diaphragm is pressed or otherwise made in dish form so that the outer supporting annulus thereof is co-planar with the center of gravity of the whole oscillating system.
28. An electro-acoustic device according to any preceding claim wherein the moving system, clamping ring and shield and stretching ring are fitted together into the base of a cup-shaped holder which forms the front portion of the microphone.
29. An electro-acoustic device according to any preceding claim wherein the coil oscillates in a radial magnetic field such as that provided by a pot magnet.
30. An electro-acoustic device according to any preceding claim wherein the magnet comprises a pot magnet formed of a central pole piece, and an outer cylinder (formed of an outer pole piece, the casing of the microphone and a rear plate) the space between the inner pole piece and the outer cylinder being preferably packed with field windings which energise the magnet.
31. An electro-acoustic device according to Claim 29 or 30 wherein the air gap of the magnet is correctly dimensioned by means of a spacing ring (of brass, cadmium bronze or other suitable material) which fits over the inner pole piece and positions the outer pole piece relatively thereto.
32. An electro-acoustic device according to Claim 29, 30 or 31 wherein the inner pole piece is made of a material of high magnetic saturation density (e.g. cobalt iron) while the outer embers may be of less permeable material (e.g. good magnetic iron).
33. An electro-acoustic device according to Claim 30, 31 or 32, wherein the field windings are formed of two different gauges of wire, the inner turns being of thinner gauge than the outer.
34. An electro-acoustic device according to any of Claims 28 — 33 wherein the cup-shaped holder carrying the moving system etc. if fitted over the face of the pot magnet (such as against a step in the outer pole piece of the magnet) so that the moving oil is correctly positioned in the magnetic air gap.
35. An electro-acoustic device according to any of Claims 24 — 34 wherein holes are drilled through the moving coil former to allow free passage of air from the space enclosed between the former, the diaphragm and the magnetic pole piece.
36. An electro-acoustic device according to any preceding claim wherein the enclosed space behind the diaphragm is sufficiently large and of such shape that undue elastic restraint on the diaphragm due to the enclosed air is avoided.
37. A microphone according to Claim 36, comprising a large, depended cavity between the front cup-shaped diaphragm-holder and the outer magnetic pole piece, with which the space immediately behind the diaphragm is in communication by a relatively narrow annular passage.

38. An electro-acoustic device substantially as described herein with reference to the accompanying drawings.
39. Sound records of any form whenever manufactured by electro-mechanical devices embodying an electro-acoustic device substantially as described herein.

Dated this 12th day of May, 1931.

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