May 30, 1950 W. J. MORELAND, JR 2,509,310

MICROPHONE OR RECEIVER OF THE CONDENSER TYPE

Filed Feb. 3, 1948

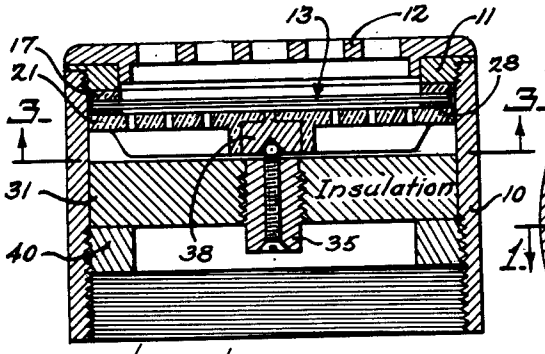


Fig. 1.

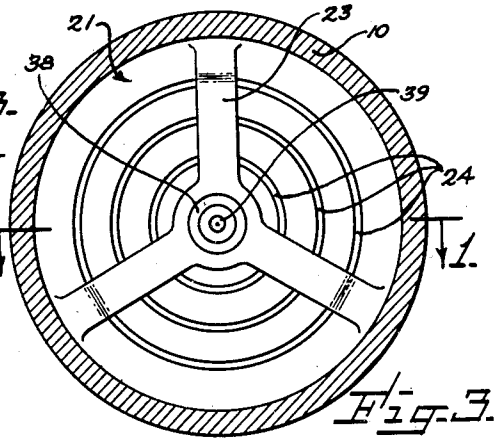


Fig. 3.

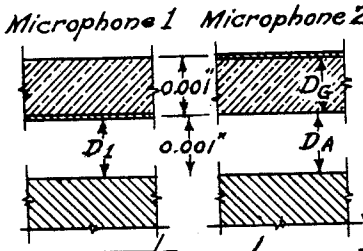


Fig. 4.

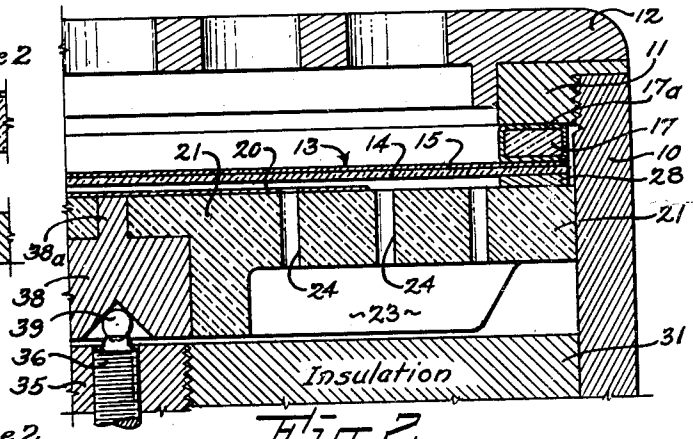


Fig. 2.

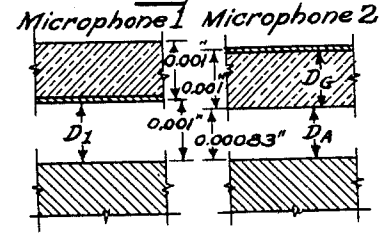


Fig. 5.

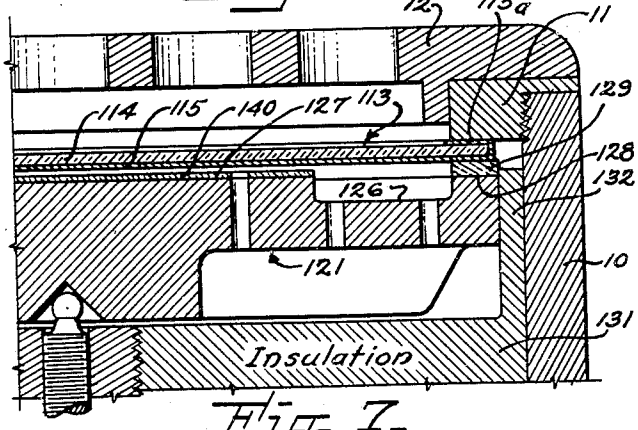


Fig. 7.

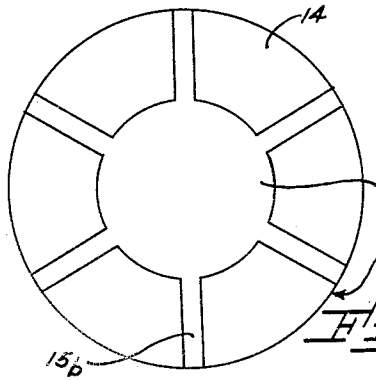


Fig. 6.

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MICROPHONE OR RECEIVER OF THE CONDENSER TYPE

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Application February 3, 1948, Serial No. 5,943

2 Claims. (Cl. 179—111)

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This invention relates generally to electro-acoustic devices of the condenser type, useful as microphonic transmitters, or as receivers, including loud speakers. The invention will be described with particular reference to its use as a microphonic transmitter, but without implying necessary limitation to that particular use.

Microphonic transmitters in use at present commonly embody a thin vibratory diaphragm of conductive material stretched to a tension which gives the diaphragm a high natural vibratory frequency. Such a stretched vibratory diaphragm forms one plate of the condenser, the other plate usually being formed by a rigid body spaced a small distance from the vibratory diaphragm. The intervening dielectric is usually air. In order to attain efficiency, the spacing must be as small as practicable in proportion to the vibrational amplitude of the diaphragm, and if the microphone is acoustically over-loaded the condenser breaks down by contact or virtual contact between the two plates. The diaphragm must be very evenly stretched in order to attain both efficiency and fidelity of response. And all of these requirements result in making such microphones quite expensive.

A general purpose and object of the present invention is to produce a condenser which may be used for the various purposes stated, and which is comparatively inexpensive to produce and is free of breakdown liability. In general, the invention typically provides a condenser structure in which the vibratory diaphragm utilizes a thin plate or wafer of a dielectric substance having a relatively high modulus of elasticity; such a substance as glass. The outer face of the wafer carries a thin coating of a conductor, such for instance as a thin metallic foil cemented on or a thin layer of metal such as aluminum deposited by the well-known vacuum-vapor process. The glass wafer may be and preferably is made very thin, and its elastic characteristics give the diaphragm a high natural vibratory frequency. The spacing between the inner uncoated face of the glass wafer and the stationary condenser plate can be very small with relation to the vibratory amplitude, resulting in high efficiency. And if the device becomes acoustically overloaded to the point where the dielectric diaphragm body contacts the fixed plate, no electrical break down occurs.

Preferred forms and designs for the invention used as a microphonic transmitter are described in detail in the following description, as illustrative of the invention. Reference is had to the accompanying drawings in which:

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Fig. 1 is a central axial section of a preferred illustrative form of microphone;

Fig. 2 is a fragmentary enlargement of certain portions of Fig. 1;

Fig. 3 is a section taken as indicated by line 3—3 on Fig. 1;

Fig. 4 is a schematic fragmentary section illustrating the relative structure and proportions of two types of microphone;

Fig. 5 is a section similar to Fig. 4, but illustrating a different selection of proportions in the second microphone;

Fig. 6 is an elevation of an alternative form of diaphragm; and

Fig. 7 is a section similar to Fig. 2, but illustrating a modification.

Referring first to Figs. 1–3, a suitable cylindric case is shown at 10, of any suitable material such as aluminum. One end of the cylindric case is provided with a member which forms an internal shoulder, such as the ring member 11 which is illustrated as screw-threaded into the outer end of the casing. Alternatively, the shoulder may be formed integrally with case 10. A perforated cover 12 may be secured over the shouldered end of case 10.

The vibratory diaphragm 13 is formed of a thin wafer 14 of relatively stiff dielectric material, such as glass, quartz or the like, finished by polishing both faces to substantially optical flatness and facial parallelism; with a conductive metallic coating 15 applied to its outer face. (See Fig. 2 for detailed structure of the diaphragm; in Fig. 1 the composite diaphragm is shown as if in edge elevation.) The diaphragm as so formed is preferably of a diameter slightly less than the interior diameter of case 10. If the metallic coating 15 is deposited by evaporation in vacuum, the circular edge of the diaphragm is shielded from the depositing metal, or, preferably, is ground to finish size after deposition of the metal so as to remove any metallic coating on the diaphragm edge. This increases the electrical leakage path between the deposited metal and the fixed electrode surface, when the latter extends across the entire width of fixed plate 21 (see below).

The diaphragm 13 may be pressed directly against internal shoulder 11 of the case (as in Fig. 7), with conductive coating 15 thus directly electrically connected to the case through metallic ring 11. A preferred structure is that shown in Figs. 1 and 2, in which a ring 17 is interposed between diaphragm 13 and shoulder 11. Ring 17 is preferably formed of glass or a similar material which can readily be ground and polished to accurate flatness, so that it will provide uniform

and non-distorting support for glass wafer 14. Coating 15 on the diaphragm can then be electrically connected to the case in various ways, for example by coating ring 17 on all its surfaces with a thin layer 17a of conductive material.

The relatively fixed plate of the condenser in the present preferred illustrative embodiment comprises a conductive layer 20 (preferably thin) which is supported by a relatively heavy stationary plate body 21 of insulative material, such as Bakelite or glass for example. Conductive layer 20 may be formed, for example, by vacuum evaporation of a suitable metal, such as aluminum, and the extent of the layer 20 can in that instance be controlled as may be desired by the well-known procedure of masking during the process of evaporation. Layer 20 preferably covers only the central portion of plate body 21, for reasons to be described. It may, however, cover the whole surface; or, what amounts to the same thing, plate body 21 may be of metal so that its surface needs no conductive coating. The back of plate body 21 is ribbed as shown at 23 to give the plate rigidity; and the face portion of the plate body is perforated, preferably by a series of concentric slots 24.

A thin spacer ring 28 of suitable easily worked and somewhat resilient material, such for example, as polystyrene, rests on the peripheral portion of the outer face of plate body 21, and bears directly against the peripheral portion of the inner face of glass wafer 14 in opposition to ring 17. Spacer ring 28, which thus determines the separation between diaphragm 13 and plate body 21, may be approximately 0.001 inch thick in a typical structure where the glass diaphragm body is about ⅜" in diameter and also about 0.001" thick.

A backing disk 31, like plate body 21, fits snugly but movably within case 20. Backing disk 31 is preferably formed of insulative material, and carries means for applying axial force to plate body 21 and for providing an electrical connection to conductive layer 20 carried thereby. As illustrated, a central metallic plug 35 is screw-threadedly inserted in backing disk 31 and carries pressure screw 36. Plate body 21 also has a central metallic plug 38, the upper portion of which (in the aspect of Fig. 1) extends, preferably with reduced diameter as at 38a, just to the upper face of the plate body, where it supports and electrically contacts the central portion of conductive plate layer 20. The lower end of plug 38 either rests upon the upper end of pressure screw 36, or upon a small steel ball 39 which rests on the pressure screw.

When the parts are assembled in the relationships shown, they are clamped in position by retaining ring 40, which is screwthreaded into the lower end of case 10. Pressure is then applied to plate body 21 by pressure screw 36 to press spacer 28 against diaphragm 13 and press the rim portion of the diaphragm firmly against ring 17 and shoulder 11. Electrical connection to the metallic facing 15 of the diaphragm may be made by connection applied to any part of the metallic casing, and connection to conductive facing 20 of plate 21 by connection to screw 36 or to metal plug 35.

The advantages provided by the invention will be understood from the preceding illustrative description and a consideration of the properties which determine the performance of a microphone in a typical application. In general it is desirable to make the electrical capacitance of the microphone, for equilibrium spacing of the plates, as large as possible; and to make the variation of the capacitance which results from a sound wave of given amplitude as large as possible, not only in absolute value, but, more especially, when expressed as a fraction of the equilibrium capacitance. If E_0 is the polarizing voltage applied to the microphone condenser, and C_0 is the static or equilibrium capacitance, the relative voltage variation dE/E_0 corresponding to a variation of capacitance dC is given by

$$\frac{dE}{E_0} = -\frac{dC}{C_0} \tag{1}$$

Thus the theoretical voltage variation dE is directly proportional to the relative capacity variation dC/C_0. For a conventional condenser microphone having an air gap D_0 and plate area A, a variation of plate spacing dD results in a relative capacity variation of

$$\frac{dC}{C_0} = -\frac{dD}{D_0} \tag{2}$$

so that

$$\frac{dE}{E_0} = -\frac{dD}{D_0} \tag{3}$$

Accordingly, for highest sensitivity the normal air gap D_0 should be small and its variation dD (for some given sound amplitude) should be large. In conventional practice, one of the factors limiting sensitivity is the possibility that momentary acoustical overloading of the microphone may cause the movable plate to contact the fixed plate, resulting in electrical breakdown of the condenser and possible damage.

An important advantage of the present invention is the fact that such electrical break-down is prevented by the presence of a dielectric layer interposed between the two plates which form the condenser. In the present illustrative embodiment, that dielectric layer is the glass wafer 14, which also forms the structural portion of vibratory diaphragm 13. Even if the diaphragm should momentarily contact the fixed plate 21 of the condenser, as may occur under extreme acoustical overload, dielectric layer 14 prevents electrical contact between plates 15 and 20 of the condenser. Thus the normal air gap between diaphragm 13 and fixed plate 20 can safely be made appreciably smaller for a diaphragm of given stiffness; or a more flexible diaphragm can safely be used with given air gap, leading in either instance to a larger relative variation of capacity dC/C_0, and hence to greater sensitivity.

A further advantage of the present invention is the superior accuracy and uniformity with which a small spacing D_0 can be established over the whole of the effective area A of the diaphragm. This is most readily accomplished by making both diaphragm 13 and the upper face of plate body 21 (as seen in Fig. 1) accurately flat. The use of glass as the structural element of the diaphragm makes possible a higher accuracy of figure than can readily be obtained, for example, with a metal diaphragm, since glass can be ground, polished and tested by precision methods familiar to the optical industry. Moreover, glass, when properly selected and worked, is almost completely free of internal strain and inhomogeneities which might lead to irregular vibratory motion or unsymmetrical modes of vibration. When glass or a similar substance is used for the diaphragm, the superior accuracy of figure per-

mits closer and more uniform spacing between diaphragm and fixed plate, and the uniform elastic properties of the glass tend to give superior fidelity of response of the microphone over the wide range of frequencies.

To take full advantage of the inherent precision of a glass diaphragm, it is desirable to provide a locating surface for the edge portion of the diaphragm which is of comparable or even greater accuracy. Such a surface is provided, according to the present invention, by the inner face of ring **17**, which is made of some material such as glass which can be worked by optical methods. That surface is then not only flat as to its general form, which may be true also of shoulder **11** against which the outer face of the ring is seated, but it is also flat in its detailed structure, being highly polished and substantially free of local irregularities. Spacing washer **28** may be worked to similar accuracy of form, but that is not ordinarily necessary if the face of ring **17** is true and if washer **28** is made of a material which is relatively soft or elastic as compared to glass.

Plate body **21**, which carries the relatively fixed condenser plate in the form of conductive layer **20**, is preferably made of some insulative material that can be accurately worked, for example by machining, as Bakelite; or by optical grinding and polishing, as glass. Central metal plug **38** must be rigidly seated in plate body **21**, so that the end of plug extension **38***a* will have a fixed relation to the face of the body. That plug end preferably lies accurately in the plane of the body face, but, because of its relatively small diameter, it may be cut slightly back from that face without significantly affecting the capacity or performance of the microphone. The metal of plug **38** and its extension **38***a* may be chosen to have a temperature expansion coefficient the same as or close to that of the plate body material. The upper end of **38***a* may then be flat-finished in the operation of finishing the surface of body **21**.

The equations given above are based on the assumption that the gap between the two plates of the microphone condenser is filled by a single medium, ordinarily air. On the other hand, in the preferred form of microphone in accordance with the present invention the space between condenser plates **15** and **20** is filled partly by air and partly by the dielectric material of the body **14** of the diaphragm. For a given free-air space between the fixed and vibratory members, the total space between the actual condenser plates is therefore greater than in a conventional structure. An important feature of the present invention is the recognition that such an increase in physical separation of the condenser plates, where the increase is caused by interposition of a dielectric layer, is of little importance in comparison with the advantages produced by that layer. The reason for this, expressed in general terms, is that such an increase in plate separation does not lead to a proportional decrease in the capacitance, nor in the relative variation of capacitance which results from a diaphragm displacement of given amplitude. The relatively high dielectric constant of the glass portion of the inter-electrode space reduces the effect of that space upon the capacitance to a small factor. For example, given an ordinary condenser with air gap D_1, and a condenser of equal area but having its plates separated by an air gap D_A and also by a constant space D_G filled with a dielectric having dielectric constant k, the ratio of their respective capacitances C_1 and C_2 is

$$\frac{C_1}{C_2}=\frac{D_A+\frac{D_G}{k}}{D_1} \tag{4}$$

Similarly, if the interplate spacing of two such condensers is varied by the same small quantity dD, the ratio of the resulting voltage variations dE_1 and dE_2 for the two condensers (assuming equal polarizing voltages) is

$$\frac{\frac{dE_1}{dD}}{\frac{dE_2}{dD}}=\frac{dE_1}{dE_2}=\frac{D_A+\frac{D_G}{k}}{D_1} \tag{5}$$

In both instances the effect of adding to an air gap D_A a space D_G filled with dielectric k is the same as if the air gap itself were increased by an amount D_G/k. Since the dielectric constant k of glass is typically about 6, the effect of adding a glass layer between the condenser plates is only about one sixth the effect of adding an equal space filled with air. For example, in the specific illustrative case of two microphones having glass diaphragms of equal thickness (D_G) 0.001'' and equal elastic properties, the first having a conductive film on the inner face of the diaphragm and the second having a similar conductive film on the outer face of the diaphragm in accordance with the invention; if both microphones have equal air gaps D_1 and D_A of, say, 0.001'', as illustrated in Fig. 4, both the capacity and the voltage response of the second microphone will be smaller than that of the first, because of the greater plate separation. But, whereas the actual plate separation of the second microphone is twice that of the first, the decrease of capacity and voltage response is found from Equations 4 and 5 to be less than 15%.

If the air gap D_G of the second microphone is reduced only 17% relative to the air gap D_1 of the first, as illustrated in Fig. 5, the capacitance and response of the two will be equal; and that in spite of the fact that the actual plate separation is still 85% greater in the second microphone than in the first. Further reduction of air gap in the second microphone, which is generally feasible for the reasons already discussed, leads to clear gain in operating characteristics.

By selecting a dielectric for the diaphragm body which has a dielectric constant greater than 6, other characteristics remaining the same, for example, the performance of the instrument can be further increased. Such a gain is not great, and the results already described may be considered as typical.

However, my invention is not limited to the use of glass as the body of the diaphragm. Other dielectric substances such as quartz, or porcelains, may be used for that body and for the plate body **21**. Generally speaking, the chosen substance, particularly for the diaphragm, should be one capable of accurate surfacing. Glass, quartz and hard porcelains are of that character and also have relatively high moduli of elasticity which is desirable to give the diaphragm a high resonant frequency.

In actual practice, the vibratory motion of a diaphragm supported peripherally is of course not uniform over its entire area, but is greatest in the central region and decreases to zero at the edge. For this and other reasons, the above analysis, although a useful simplification, par-

ticularly when applied to a restricted element of area of the diaphragm surface, does not give a complete picture of the performance characteristics of a microphone. The primary result of the radial variation in the amplitude of vibration of the diaphragm is that the outer portions of the condenser plates contribute to the total static capacitance C_0 of the condenser without contributing a fully equivalent amount to the variation dC of that capacitance. Thus the relative variation of capacitance dC/C_0 is smaller for the outer portions of the plate than for the central portion, and the overall value of dC/C_0 for the entire condenser, which determines the relative voltage variation, is reduced.

This effect is partially avoided by the present invention by limiting one or both of the electrically conductive condenser plates (in the embodiment illustrated in Figs. 1–3, the relatively fixed plate 20) to the central area of the vibratory diaphragm. The outer portions of the diaphragm, where the amplitude of vibration is greatly reduced, then do not affect the value of dC/C_0, since they do not contribute appreciably either to dC or to C_0. Although the conductive layer 15 on the diaphragm itself extends over the whole of the diaphragm face, it produces negligible electrical capacity except in those portions which are immediately adjacent the relatively small fixed plate 20. A further advantage of limiting the effective condenser area to less than the diaphragm area is that the leakage path between the condenser plates is greatly increased.

The same result is obtained by any structure which limits the effective portion of the condenser to the central region of the circular vibratory diaphragm. Thus, the conductive layer 15 on the diaphragm itself may be mainly limited to the central region of the diaphragm, and the relatively fixed plate 20 may then be similarly limited, or may extend opposite the whole of the vibratory diaphragm. Connection to such a central conductive layer (see 15*a* in Fig. 6) can then be made, for example, by coating relatively narrow strips 15*b* which extend from the central layer to the peripheral portion of the diaphragm 13*a*. The uncoated areas between strips 15*b* are preferably made fairly narrow to prevent stray fields from disturbing the performance of the microphone; or the cover 12 may be formed as an electrical shield to reinforce the shielding action of the apertured coating 15*a*.

If it is preferred to make the relatively fixed plate 21 of solid metal, an alternative structure such as that indicated in Fig. 7 is preferred. Backing plate 31, which is of insulative material (Fig. 3), is then formed as shown at 131 in Fig. 7 with an upwardly extending rim 132 which encloses the periphery of metal plate 121 and insulates it from case 10. The outer face of plate 121 can then be cut back to form a channel as at 126, leaving a central portion 127 closely adjacent the vibratory diaphragm 113 and a narrow rim portion 128 which supports the diaphragm. The capacitance associated with rim portion 128 is small, since the rim is relatively narrow and its surface may be lower than surface 127; and that associated with the channeled area 126 is small because its spacing from vibratory diaphragm 13 is there relatively large. Hence the effective capacitance of the microphone is mainly that associated with central plate portion 127 of plate 121. Since this lies opposite the central portion of the vibratory plate, where the vibrational amplitude is relatively large, the effect of channel 126 is to increase the value of dC/C_0 in much the same manner that has been described in connection with the limited area conductive layer 20 in Figs. 1 and 2.

Fig. 7 illustrates certain other modifications of the embodiment of Figs. 1–3. In Fig. 7 the glass ring 17 of Figs. 1 and 2 is omitted, and the diaphragm 113 is shown as pressed directly against case flange 11, although the glass bearing ring 17 may also be interposed as in Fig. 2. The diaphragm itself in Fig. 7 is again shown as formed of a thin conductive layer 115 carried by a diaphragm body 114, which is again preferably but not necessarily a wafer of such a dielectric material as previously discussed; but the conductive layer is in this instance on the inner or lower face of the diaphragm, adjacent plate 121. In order to provide an insulating or dielectric layer between condenser plates 115 and 121, a thin layer of insulative or high dielectric material 140 is applied to the central portion 127 of plate 121. This layer 140 may, for example be a thin wafer of glass or similar substance cemented to the face of plate 121. If this wafer has appreciable thickness, spacing ring 129 is thickened correspondingly to maintain the desired free space below the central portion of vibratory diaphragm 113. This spacing ring may be of any suitable insulative material, e. g. of glass finished as described for ring 17. Electrical connection between layer 115 and the case may be had, for instance, by extending that layer as at 115*a* around the edge of wafer 114 to contact the metallic shoulder ring 11.

With the structure just described, the thickness and material of body portion 114 of diaphragm 113 can be chosen to give the most desirable vibratory properties, without any regard to the capacity of the microphone condenser, the latter being determined by the air gap and the thickness of protective dielectric layer 140, which may be supported over its entire area by plate 121.

I claim:

1. An electrical condenser of the type described, comprising a tubular metallic shell having an internal annular shoulder near its outer end, a seating ring of glass-like material seated against the shoulder and having an inner polished flat face, a vibratory diaphragm in the shell with the peripheral portion of its outer face engaging the inner face of the seating ring, said diaphragm comprising a radially unstressed thin wafer of a glass-like material having polished flat parallel faces and a thin layer of conductive material on its outer face, an annular spacer lying against the peripheral portion of the inner diaphragm face, a relatively fixed plate comprising a body of dielectric material having an outer flat surface with its peripheral portion bearing against the annular spacer and a thin layer of conductive material on, and restricted to the central portion of, its outer flat surface, and means secured in the inner end of the case pressing against the inner face of the fixed plate to press it against the glass-like wafer to hold the wafer against the seating ring and the seating ring against the shoulder, the bearing of the wafer against the seating ring and of the spacer ring against the wafer being such as not to appreciably stress the wafer in its own plane.

2. An electrical condenser of the type described, comprising a tubular metallic shell having an internal annular shoulder near its outer end, a seat-

ing ring seating against the shoulder, a vibratory diaphragm in the shell with the peripheral portion of its outer face engaging the inner face of the seating ring, said diaphragm comprising a radially unstressed thin wafer of a glass-like material having polished flat parallel faces and a thin layer of conductive material on its outer face, an annular spacer lying against the peripheral portion of the inner diaphragm face, a relatively fixed plate comprising a body of dielectric material having an outer flat surface with its peripheral portion bearing against the annular spacer and a thin layer of conductive material on, and restricted to the central portion of, its outer flat surface, and means secured in the inner end of the case pressing against the inner face of the fixed plate to press it against the glass-like wafer to hold the wafer against the

seating ring and the seating ring against the shoulder, the bearing of the wafer against the seating ring and of the spacer ring against the wafer being such as not to appreciably stress the wafer in its own plane.

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