June 24, 1947. W. E. GILMAN 2,423,014

PRESSURE-EQUALIZING HOUSING FOR TRANSDUCERS

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FIG. 1.

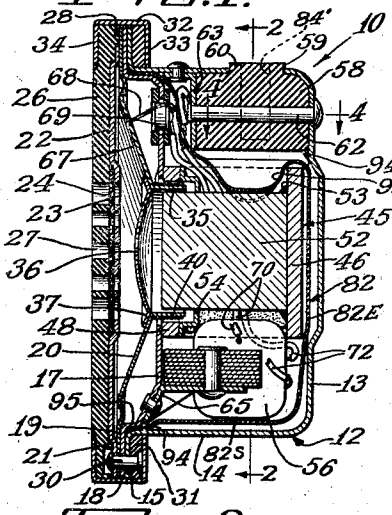


FIG. 2.

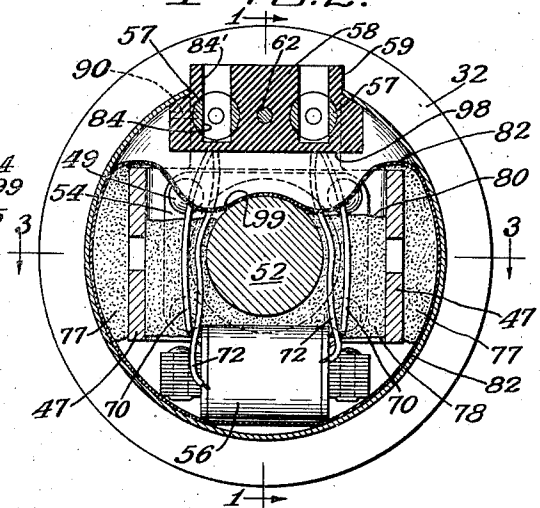


FIG. 3.

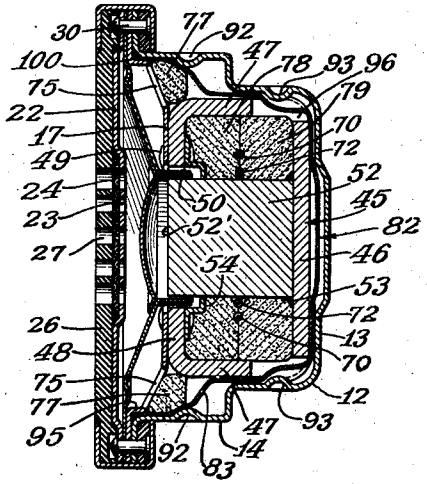


FIG. 5.

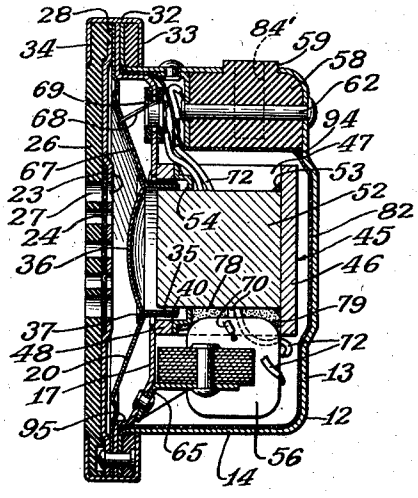


FIG. 4.

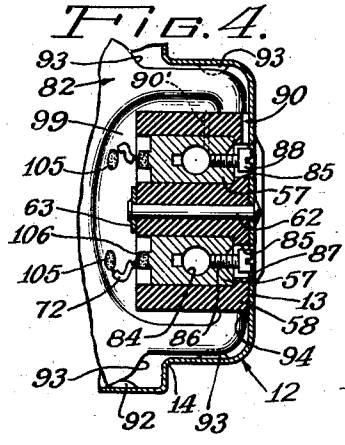


FIG. 6.

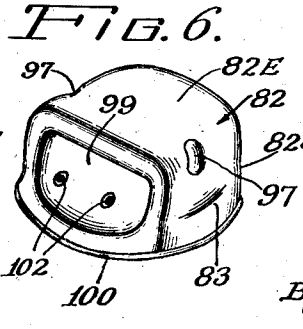


FIG. 7.

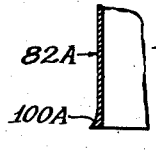
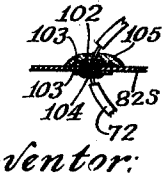


FIG. 8.



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Fig. 9.

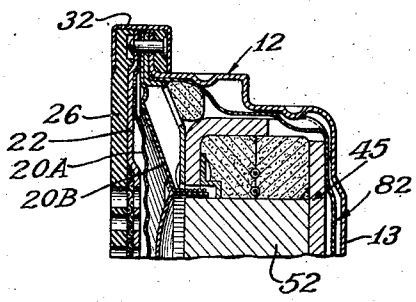



Fig. 10.

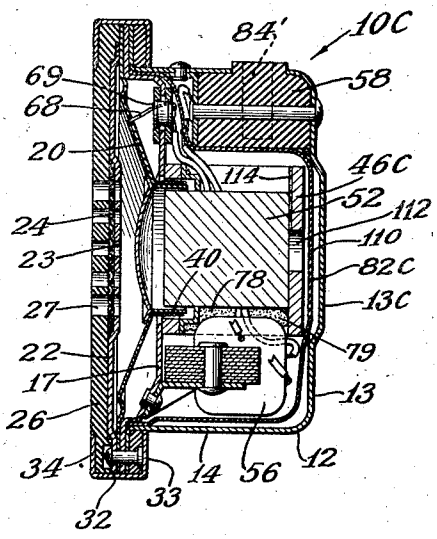



Fig. 11.

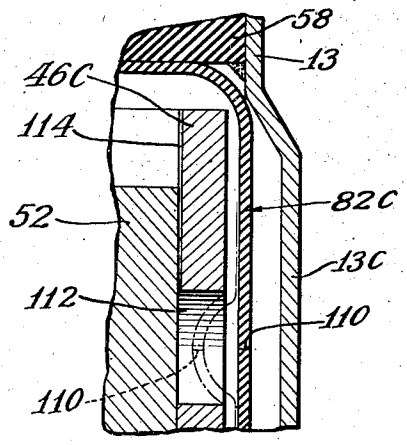



Fig. 13.

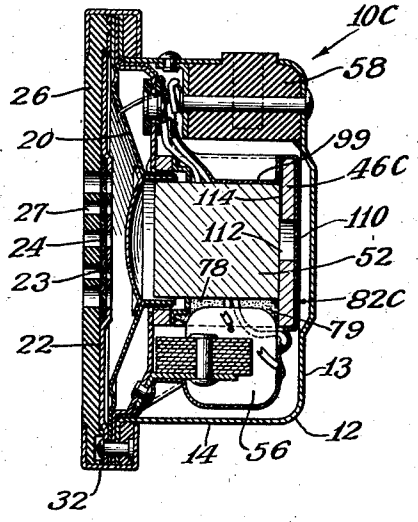
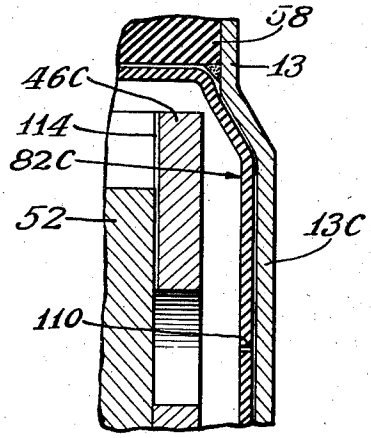



Fig. 12.




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2,423,014

# UNITED STATES PATENT OFFICE

2,423,014

## PRESSURE-EQUALIZING HOUSING FOR TRANSDUCERS

Webster E. Gilman, Chicago, Ill., assignor to Permoflux Corporation, Chicago, Ill., a corporation of Illinois

Application May 10, 1943, Serial No. 486,285

9 Claims. (Cl. 179—179)

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This invention relates to transducers, and particularly to transducers wherein the electrical elements and the air gap are sealed and protected against the entry of objectionable foreign substances such as dust, grit, fibers, water or water vapor.

The contingencies against which a transducer is to be sealed vary, of course, with the known conditions of use which it is to encounter, and in some instances where the transducer is to be used in a dry or arid climate, such sealing may be directed primarily against the entry of dust grit and other dry substances. In such a case, the problem of water or water vapor is disregarded and the sealing means may be non-waterproof in character. Under other circumstances the transducer may be intended for use in a wet or humid climate where the sealing means must also serve to exclude water and water vapor from the electrical parts and the air gap of the transducer. In either instance, such sealing of transducers involves the use of an imperforate means in the form of a flexible imperforate membrane or an imperforate diaphragm which is so associated with the housing of the transducer that this imperforate means and the housing completely enclose and protect the operative electrical elements of the transducer which are disposed back of the diaphragm. Thus a closed back chamber has been afforded in such sealed transducers, and as a solution of the problem of excluding foreign material, apart from other problems involved in such transducers, such a closed back chamber construction might be considered satisfactory. However, it will be recognized that transducers must, in their transducing action, preserve maximum intelligibility of the sound impressed thereon or reproduced thereby, and to attain such intelligibility, the output level as well as the frequency response characteristics of the transducers must, under all conditions of use, be maintained within predetermined limits of variation throughout a prescribed range of frequencies. Where a closed back chamber is adopted in an effort to protect the electrical elements of a transducer against foreign substances, it has been found that this expedient materially complicates the attainment and maintenance of the required output level and the required frequency response characteristics of the transducer under the varying conditions encountered in use.

For many important kinds of use it has been determined that a frequency response curve which is substantially flat between one hundred cycles and four thousand cycles, attains maximum intelligibility so long as the output is maintained at the proper level, and it has been found that response characteristics having the proper output level and conforming within permissible tolerance limits to such a frequency response curve, may be attained in sealed transducers of the magnetic,

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carbon button, condenser, crystal or dynamic type, as for example in the manner disclosed in my copending application Serial No. 466,903, filed November 25, 1942, which illustrates and describes several embodiments of sealed dynamic transducers which will attain such desired response characteristics. As shown and described in my aforesaid copending application in respect to one of the disclosed embodiments, the desired flat frequency response curve is attained at least in part through the provision of damping or energy dissipating means afforded by packed masses of fibrous material such as kapok in the back chamber to absorb the energy of air in the back chamber as this confined air is repeatedly compressed by the vibratory movements of the diaphragm.

Where such a frequency response curve has been established in a transducer, it is of course desirable to maintain this same frequency response curve as well as the desired output level under the varying conditions encountered in the use of the transducer, but in prior sealed transducers this desired retention of the original frequency response characteristics and output level have been impossible where wide variations of external air pressure are encountered, as for example, in high altitude flying or where heavy concussions are encountered which tend to mechanically load the diaphragm or to deform or in some cases break the diaphragm. It will be evident that when a sealed transducer of the construction heretofore used is assembled at or near sea level, the air enclosed or trapped within the sealed back chamber will be at substantially sea level pressure, so that this trapped body of air exerts a predetermined forward or outward pressure on the inner face of the diaphragm which, at sea level, is equal to the inward air pressure exerted by atmosphere on the outer face of the diaphragm. Thus, the air pressure, at sea level, is equal on both faces of the diaphragm, and this condition prevails when the transducer is originally constructed, adjusted and tested to produce the desired output characteristics and the desired frequency response curve.

When, however, such a prior sealed transducer is used in high altitude flying, or is subjected to the violent compressions and rarifications of air pressure incident to some forms of concussions, the decrease of the external air pressure applied to the outer face of the diaphragm results in the application of substantial outward forces upon the diaphragm by the trapped air within the closed back chamber, and this in some instances ruptures or breaks the diaphragm, and in all instances constitutes an effective mechanical loading which materially reduces the output response and also varies the frequency response characteristics of the transducer. Thus, when a conventional sealed transducer is used at high altitudes, the desired intelligibility in the transduced

output is objectionably reduced by the combined action of the reduced output level and the objectional variation from the optimum frequency response curve of the transducer, and to improve the altitude response characteristics of sealed transducers so as to minimize such loss of intelligibility at high altitudes is an important object of this invention. Another important object is to enable such transducers to be effectively sealed in such a manner as to protect the diaphragms thereof in a mechanical sense against objectionable deformation or breaking of such diaphragms which would otherwise result from violent concussions and the like.

Further objects of the invention are to enable transducers to be sealed in such a manner that the acoustical response characteristics of the transducers are not altered at sea level pressures and are maintained within relatively close ranges of variation as the transducers are used at higher altitudes; to maintain a constant and relatively low humidity level within the back chambers of transducers, thereby to prevent formation of ice in loading passages or the fibrous loading material used in such back chambers or in the air gap of such a transducer; to maintain substantially constant humidity conditions in the loading passages or fibrous loading material of such back passages so as to prevent undesired variation in the output or the frequency response of the transducers, and to protect the moving parts and particularly the air gap of such transducers against dust and dirt as well as other foreign material such as water.

In my aforesaid copending application, I have illustrated and described a dynamic transducer which, in one of its embodiments, is sealed in such a manner as to provide for limited equalization of the air pressure on opposite sides of the diaphragm, and with the construction therein shown it is possible to maintain the performance characteristics of the transducer in relatively low altitude flying, or for relatively small decreases in atmospheric pressure. The specific construction thus shown in the aforesaid copending application is simple in construction, and where but small variations in atmospheric pressure are contemplated, such construction will preserve intelligibility of transduction within permissible limits of variation. However, it has been found that the particular conditions of use to which a particular transducer is to be subjected cannot always be predicted, so that as a practical matter it is desirable that the transducers have an altitude response which will be acceptable and satisfactory for all altitudes which may be encountered in the general field of use for which they are intended, and to enable this to be accomplished is a further object of the invention. Other objects related to the foregoing are to enable the maximum improvement of altitude response in sealed transducers to be attained in each particular size and design of transducer; to attain this result without enlargement or other undesirable modifications in the size, shape or other characteristics of a transducer; to enable such results to be attained by means which are simple and effective in character; and to utilize the internal volume of the transducer to its maximum efficiency in affording space for expansion of the air trapped about the electrical means of the transducer.

Where the sealing of a transducer is such as to render the same proof against the entry of water or water vapor the requisite equalization of the air pressure on the front and rear faces of the diaphragm must be maintained by expansion of the air trapped behind the diaphragm, and where an unusually large size in the transducers is permissible, this may, in accordance with one aspect of the present invention, be attained for any altitude ordinarily encountered in flight. However, when the size of the transducers must be maintained at the minimum, and the transducers are to be used at unusually high altitudes, the required expansion of the trapped air cannot take place within the confines of the housing of a transducer. It is, therefore, a further object of this invention to enable a transducer to be sealed in such a manner that pressure equalization on the opposite faces of the diaphragm is attained at low altitudes by expansion of the air trapped in the back chamber and is attained at higher altitudes by breathing or passage of air into or out of the back chamber, thereby to protect the critical elements of the transducer at lower altitudes where objectionable humidity conditions may exist, while permitting relatively free breathing of the transducers at higher altitudes where low temperatures eliminate objectionable humidity. An object related to the foregoing is to seal transducers by waterproof distensible means which includes a pressure responsive valve means which is closed at low altitudes and is automatically opened at higher altitudes, thereby to enable air pressures to be equalized in different ways which are related to the altitude and to the probable humidity conditions which may be encountered.



Other and further objects of the present invention will be apparent from the following description and claims and are illustrated in the accompanying drawings which, by way of illustration, show preferred embodiments and the principle thereof and what I now consider to be the best mode in which I have contemplated applying that principle. Other embodiments of the invention embodying the same or equivalent principle may be used and structural changes may be made as desired by those skilled in the art without departing from the present invention and the purview of the appended claims.

In the drawings:

Fig. 1 is a transverse sectional view at an enlarged scale of a transducer embodying the features of the invention, the view being taken along the line 1—1 in Fig. 2;

Fig. 2 is a cross sectional view of the transducer taken along the line 2—2 of Fig. 1;

Fig. 3 is a sectional view taken along the line 3—3 in Fig. 2;

Fig. 4 is a fragmental sectional view taken along the line 4—4 in Fig. 1;

Fig. 5 is a sectional view similar to Fig. 1 and illustrating the form assumed by the protective or sealing sheath when the transducer is used at high altitudes;

Fig. 6 is a perspective view illustrating the protective sheath utilized in the embodiment of the invention shown in Figs. 1 to 5;

Fig. 7 is a fragmental sectional view showing the side wall formation of an alternative embodiment of the sheath;

Fig 8 is an enlarged fragmental sectional view illustrating the manner in which the connecting wires are extended in sealed relation through the protective sheath;

Fig. 9 is a fragmental cross sectional view similar to Fig. 3 and showing the manner in which

a supplemental diaphragm may be associated with the main diaphragm in some instances;

Fig. 10 is a view similar to Fig. 1 and illustrating an alternative embodiment of the invention;

Fig. 11 is an enlarged portion of Fig. 10;

Fig. 12 is a view similar to Fig. 11 and showing the relationship of the parts at extremely high altitudes; and

Fig. 13 is a view similar to Fig. 10 and showing the relationship assumed by the protective sheath after the transducer has been used at high altitudes.

For purposes of disclosure the invention has been herein illustrated as embodied in a transducer 10 of the dynamic type, but it is to be recognized that in many of its aspects the invention may be utilized with transducers of the magnetic type, the carbon button type, the condenser type, or the crystal type. The dynamic transducer 10, as herein shown, is quite similar in form and construction to one of the embodiments illustrated and described in my aforesaid copending application, and this transducer embodies a cup-shaped housing 12 formed from a ferrous material to afford a bottom or back wall 13, a generally cylindrical side wall 14, and an integral mounting flange 15 which extends outwardly from the open end of the side wall 14. The flange 15 of the housing 12 serves as a mounting means upon which the internal elements of the transducer are supported, and such elements are supported by means including a mounting plate 17 which terminates in a flange 18 disposed in flat surface abutment with the face of the flange 15. In the present instance the flange 18 of the mounting member 17 affords a supporting surface against which the outer mounting flange 19 of a diaphragm 20 is disposed, and preferably the flange 19 is sealed in a waterproof relation to the flange 18 by a suitable adhesive or lacquer. In the preferred form of the invention which is herein shown the mounting flange 19 of the diaphragm 20 is held in position by the mounting flange 21 of a shield plate 22, this shield plate being formed from a ferrous material and having openings or perforations 23 therein so that sound energy may pass therethrough. The openings 23 are preferably covered by a fabric shield 24, and the outer surface of the shield plate 22 is covered by a cap plate 26 which is formed from an insulating material such as a cast phenolic resin. The cap plate 26 has openings 27 therein which are maintained in registry with the openings 23 by an interlocked arrangement 28 acting between the cap plate 26 and the shield plate 22.

The shield plate 22, the diaphragm 20, and the mounting plate 17 are held in position by means such as rivets 30 which extend through the flanges 15, 18, 19 and 21, as shown in Fig. 1 of the drawings, and in the present instance the rivets 30 also extend through a spacer ring 31 which is disposed about the side wall 14 and in abutting relation to the rear face of the flange 15 of the housing. The cap plate 26 is held in place by a securing ring 32 which surrounds the edges of the flanges 15, 18, 19 and 21 and is flanged inwardly at 33 and 34 so as to engage the exposed border faces of the spacer ring 31 and the cap plate 26 so as to thereby clamp the several parts in assembled relation.

The diaphragm 20 is preferably formed so as to be imperforate, and when so constructed the diaphragm may serve to prevent entry of dust and like materials into the housing through the



front thereof, and the electrical means which are associated in an operative transducing relation to the diaphragm 20 are disposed behind the diaphragm 20 and within the housing 12. In the form shown in Figs. 1 to 5 of the drawings the imperforate diaphragm 20 is made from a flexible and waterproof material so that it also serves to exclude water and moisture, but in some instances the attainment of the desired frequency response in the diaphragm 20 may require breather openings in the diaphragm, or may require its construction from a non-water-proof material, and in such a case the front of the transducer may be sealed by a protective membrane 20A disposed loosely across the front of the diaphrgam 20B in spaced relation thereto as shown in Fig. 9 of the drawings. In such a construction the membrane 20A constitutes a functional part of the diaphragm means, and is actuated with the diaphragm 20B. In the form shown in Figs. 1 to 3 and 5, the diaphragm 20 is generally conicle in form and has a cyllindrical coil support 35 formed integrally with the conicle portion of the diaphragm so as to project rearwardly therefrom. The forward end of the voice coil support 35 is closed by a cap 36 which is also formed from waterproof material and is secured about its edges at 37 as by an adhesive or lacquer to the conicle portion of the diaphragm 20 so as to afford a water tight connection betwen the cap 36 and the conicle portion of the diaphragm.

The voice coil support 35 has relatively fine wire wound thereabout to afford a voice coil 40, and electrical means are afforded within the housing 12 to cooperate with the voice coil 40 in attaining the desired transducing action. In the present instance such electrical means comprise a magnetic circuit for cooperation with the voice coil 40, and such a magnetic circuit includes a box-like magnetic yoke 45 formed from a relatively thick and wide strip of ferrous material to provide a bottom member 46, side members 47, and a top member 48, as shown in Fig. 3 of the drawings. The top member 48 is secured to the mounting member 17 by means including rivets 49, and a circular opening 50 is formed in the top member 48 of the yoke to define the outer side of the magnetic gap of the magnetic circuit. The inner side of the magnetic gap is, in the present instance, defined by the cylindrical outer surface of a permanent magnet 52 which, as herein shown, is of solid cylindrical form. The magnet 52, when thus formed, is rested against the bottom member 46 of the magnet yoke in flat surface contact therewith and the magnet is secured in position as by soldering as at 53. The magnet 52 must, of course, be centered with respect to the opening 50, and this is accomplished by a positioning member 54 made from a non-magnetic material such as brass and secured in position by the rivets 49. The positioning member 54 engages the sides of the magnet 52 in inwardly or rearwardly spaced relation to the outer end 52' of the magnet 52, thereby to afford ample clearance space for reciprocation of the voice coil within the magnetic gap.

The voice coil 40 is connected, by means including a transformer 56, to a pair of terminals 57 which are mounted in a terminal block 58. The terminal block 58 is mounted on the inner face of the side wall 14 of the housing 12 and has a neck portion 59 which extends snugly through an opening 60 formed in the side wall 14, and the terminal block 58 is held in position by means including a mounting rivet 62 and a

mounting bracket 63 disposed within the housing. The transformer 56 is disposed within the housing 14 at a point diametrically opposite from the location of the terminal block 58, and the transformer is supported in the desired position within the housing by a mounting bracket 65 which is riveted onto the rear face of the mounting plate 17 as shown in Fig. 1. The voice coil 40 is connected to one of the windings of the transformer 56, and this connection includes wires 67 which, as shown in Fig. 1, are extended in spaced relation from the ends of the voice coil 40 and through the diaphragm 20 adjacent through the voice coil. The wires 67 are extended in outward radial directions along the outer face of the diaphragm 20 and near the edge thereof these wires are extended through the diaphragm as at 68. The points at which the wires 67 pass through the diaphragm 20 are sealed and rendered water-tight by the application of a waterproof lacquer or the like. The ends 68 of the wires 67 are extended through spaced metal bushings 69 mounted in insulated relation in the mounting plate 17 and are soldered to the bushings 69 so as to be electrically connected thereto. Wires 70 are similarly soldered to the bushings 69 and are extended and connected to one of the windings of the transformer 56. The connection of the voice coil to the terminals 57 is completed by wires 72 in a manner which will hereinafter be explained in detail.

It will be observed that the mounting plate 17 has a pair of relatively large openings 75 formed therein, as shown in Fig. 3 of the drawings, and thus the entire interior of the housing 14 constitutes a back chamber for the transducer. Since the back chamber which is thus formed is, in effect, closed, the successive compressions of the air within such back chamber by the vibrating diaphragm 20 tends in some instances to adversely influence the frequency response characteristics of the transducer, and to control this objectionable action of the confined air, the back chamber is provided in the present instance with means for dissipating or absorbing the energy of the air as it is successively compressed. As best shown in Figs. 1, 2 and 3, this end is attained through the provision of fibrous pads 77, 78 and 79 of wool or the like within the back chamber. The fibrous pads 77 are disposed along the back face of the mounting plate 17 outside of but adjacent to the end members 47 of the magnetic yoke 45, these pads 77 being secured in position by a suitable adhesive so as to extend over the openings 75. The pads 77 thus act to prevent a resonance peak in the response curve which might otherwise result at a point determined by the dimensions and volume of the air chamber formed between the mounting plate 17 and the diaphragm 20. The pads 78 and 79 are somewhat U-shaped in form, as will be evident in Fig. 2 of the drawings, and these two pads are inserted into the space between the members 46 and 48 of the magnetic yoke 45. The pads 78 and 79 are arranged to embrace the magnet 52 and to extend between the magnet and the transformer 56 as shown in Figs. 1, 2 and 5. The pads 78 and 79 terminate, as at 80, so that they do not extend entirely about the magnet 52, and as herein shown the two pads 78 and 79 are of substantially equal thickness so that the wires 70 and 72 may be extended therebetween as shown in Fig. 3 of the drawings.

It will be clear that the electrical means which are supported within the housing 12 by the mounting plate 17 are protected, in part, against the entry of foreign material by the imperforate diaphragm 20, the border flange 19 of which is clamped in a sealed flat surface contact with the flange 18 of the mounting member 17, and in accordance with the present invention, as disclosed in Figs. 1 to 8, a distensible and imperforate sheath means 82 is disposed within the housing 12 and about the electrical means and is so associated with the diaphragm 20 that the electrical means are completely protected against the entry of foreign substances. The imperforate sheath means 82 is so formed and related to the electrical means that the sheath means normally hugs quite close to the exterior bordering surfaces of the electrical means so as to minimize the amount of air enclosed or trapped within the sheath means and thus the sheath is spaced away in varying and in most instances substantial amounts from the internal surfaces of the housing 12. Hence, when the air pressure is reduced outside of the sheath means, the air within the sheath means may expand so as to dilate or distend the sheath means into the surrounding space and toward the internal surfaces of the housing.

In order that the air pressure in the space between the housing 12 and the sheath 82 may equalize with the external air pressure which is effective on the forward face of the diaphragm, the housing 12 is arranged to afford an air passage which for best results is maintained relatively small so as to insure gradual equalization of the internal air pressure with the external pressure. To afford such an air passage the present embodiment of the invention makes use of the terminal block 58 and the particular construction and relation thereof to the housing. Thus, as will be clear from a comparison of Figs. 2 and 4, the terminal block 58 is molded from an insulating material to include spaced metal inserts which provide the terminals 57, and each metal insert or terminal has a bore or socket 84 formed therein which is aligned with a corresponding bore 84' molded in the terminal block, and the bores 84' open outwardly through the extended neck portion 59 to enable a plug terminal or tip to be inserted therein and into conducting relation with the related terminal 57. One face of the terminal block 58 is located in abutment with the internal face of the wall 13 of the housing 12, as shown in Figs. 1 and 4, and this face has relatively large bores 85 formed therein which are aligned with screw threaded bores 85 formed in the respective terminals 57 and with openings 87 formed in the wall 13. The bores 86 are arranged to open into the sockets 84, and set screws 88 are extended through the openings 87 and the sockets 85 and are threaded into the bores 86 so that they may be used to fasten connector tips or the like in the sockets 84.

With this construction the desired air passage into the housing 12 is provided by molding a slot 90 in the surface of the terminal block 58 which abuts the wall 13, and this slot 90 is arranged to extend from one of the bores 85 to the adjacent end edge of the terminal block 58 as shown in Figs. 2 and 4. Thus, air may pass through the passage afforded by the slot 90 and through the associated bore 85 and the opening 87 to the exterior of the housing 12. The rate of such air travel through the passage 90 is controlled and governed by the cross sectional area of the slot, and in order to insure that such

movement of air into and out of the housing will be governed solely by the passage 90, the other points at which air might enter or leave the housing are effectually sealed by the application of lacquer or like material on the inner surface of the housing. Thus, such lacquer is applied to the inner surfaces of the two pairs of mounting sockets 92 and 93 which are formed in the side wall 14, for it is found that in some instances the metal is torn about these sockets so as to form small openings through which air may pass. Similarly, the lines of juncture of the terminal block 58 with the walls 13 and 14 of the housing are sealed as at 94, Figs. 1, 4 and 5, but it will be noted that no lacquer is applied along that line of juncture where the slot 90 opens into the interior of the housing, for such an attempt to seal this line of juncture might inadvertently result in closure of the slot 90. In other instances the slot 90 may be eliminated and the desired air passage may be afforded by a bore 90' extended into the terminal block 58 as shown in Fig. 4 so as to meet one of the bores 84 at a point near the side of this bore where the set screw 88 enters. Thus the tightening of the set screw 88 to secure a connector tip in place forces this tip to one side of the bore and thereby affords a continuation of the passage 90'.

It has been pointed out hereinbefore that the sheath 82 normally hugs quite closely about the border or outer surfaces of the electrical means of the transducer, and is capable of distention outwardly toward the interior surfaces of the housing 12 when the air pressure outside of the sheath is reduced, and it will be recognized that the required distensibility of the sheath 82 may be afforded in different ways. Thus, the sheath may be made from an elastic and flexible material such as rubber which will stretch to the required size or form in response to changes of air pressure, or the sheath may include an excess of flexible material which is so formed and arranged that it may change its form or position, to thereby attain the desired distention of the sheath 82 without stretching, as the differences in air pressure become effective thereon. In the form herein shown the required range of distention of the sheath 82 is attained through a combination of these two methods, and the sheath is formed from rubber or other stretchable resilient material so that a portion of the required distention is attained without stretching through change or reversal of form of one or more parts of the sheath which are specially formed or shaped to enable this to take place, while the balance of the required distention is attained by stretching of the material of the sheath.

To attain such distensibility in the sheath 82, a rubber latex material is preferably utilized and this material is formed by the conventional process of dipping a mold into the latex to the desired level to form a thin rubber sack or cup-like member about the mold, and a substantially cup-shaped sheath 82, as shown in Fig. 6, thereby produced. The mold about which the thin rubber sheath is thus formed is of such a size and shape that the sheath has a relatively flat end wall 82E and a generally cylindrical side wall 82S, Figs. 1 and 6, but the general form thus afforded by the walls 82E and 82S is modified in accordance with the general external form of the electrical means so that the related or adjacent portions of these walls of the sheath will hug closely to the electrical means and will extend into at least some of the larger outwardly facing cavities or spaces which are afforded in and about the elements of the electrical means. Thus, as shown in Fig. 3, the side wall 82S must extend over and outside of the pads 77, but just to the right of these pads, as shown in Fig. 3, the side wall 82S is formed so as to bend inwardly at 83 toward the end members 47 of the magnetic yoke, thereby affording a relatively large space at these points between the sheath 82 and the side wall 14. Similarly, at the point where the side wall 82S is to be opposite the transformer 56, as shown in Fig. 1, the sheath 82 is formed so as to bear against the adjacent face of the transformer, while adjacent the left hand edge of the sheath, the wall 82S is molded so as to bend outwardly as at 94, thereby to enable the edge portion of the sheath to be readily extended over the cylindrical securing portion 95 of the mounting plate 17.

It will be observed that in the form herein shown the side members 47 of the magnetic yoke 45 are slotted at 96 to afford clearance for the inwardly projecting portions of the metal which forms the sockets 93, and where such a form is present in the electrical means, corresponding inwardly extended cavities 97 are formed in the side walls 82S so that the sheath in these areas will normally extend into the slots 96, as shown in Fig. 3 of the drawings. When, however, the air pressure outside of the sheath 82 is reduced below the pressure of the air within the sheath, the walls of the cavities 97 may reverse their form so as to project outwardly to the extent permitted by the opposed internal surfaces of the housing 12. Thus the distention of the sheath 82 which is obtained by such reversal of the positions of the walls of the cavities 97 does not involve stretching of these portions of the sheath.

The distention of the sheath which is thus obtained by reversal of position of parts of the wall of the sheath is particularly advantageous in that relatively large volume changes in the sheath may be attained without tensioning or stretching of the sheath, and hence this arrangement is employed whenever a relatively great space is available between the electrical means and the opposed inner surface of the housing or the parts mounted thereon. Thus, as shown in Figs. 1 and 2, the pads 78 and 79 extend about the magnet 52 so as to fill but a portion of the space within the magnetic yoke 45, and this arrangement affords a considerable space between the surface 98 of the terminal block 58 and the adjacent surfaces of the magnet 52 and the pads 78 and 79. This relatively large volume space is utilized by forming the side wall 82S of the sheath 82 with a relatively large recess or cavity 99 so that the walls of this cavity will normally extend into this space as shown in Figs. 1 and 2 and will lie against or relatively close to the adjacent side surface of the magnet 52. With this form and arrangement of the cavity 99 in the sheath 82, the volume of the sheath may be greatly increased without stretching of the sheath, for upon decrease of the external air pressure the wall of the cavity 99 may move outwardly toward or into contact with the surface 98 of the terminal block, such contact being shown in Fig. 5 of the drawings.

The open end of the sheath 82 must, of course, be associated with the forward sealing means such as the imperforate diaphragm 20 or the membrane 20A so as to completely seal the electrical means against the entrance of foreign substances, and in accomplishing this the embodiment of the invention shown in Figs. 1 to 8

utilizes a portion of the mounting plate 17. It will be recognized, however, that in some instances such association of the sheath and the diaphragm 20 or the membrane 20A might be by direct contact of these elements, or might be through the medium of means other than a supporting plate or the like. In attaining the desired seal between the diaphragm 20 and the sheath 82 in the present embodiment of the invention, the cylindrical wall portion 95 of the mounting plate 17 is extended for a short distance from the flange 18 so as to be disposed in opposed and slightly spaced relation to the internal surface of the side wall 14 of the housing 12, and this relationship is continuous entirely about the side wall 14. Thus the edge of the side wall 82S of the sheath 82 may be disposed so that it embraces the wall 95 continuously about the entire periphery of the wall 95, and by establishing a sealed relation between this edge portion of the sheath and the wall 95, the interior of the sheath may be effectually sealed against the entry of foreign substances. In this connection it will be observed that the wall 95 and the portion of the flange 18 inwardly of the rivets 30 are both imperforate, and hence the sealing of the diaphragm 20 and the sheath 82 to the flange 18 and the wall 95, respectively, produces the desired sealing of the interior of the sheath.

In the present instance the desired seal between the sheath 82 and the wall 95 is established solely by a clamping action, and to facilitate this mode of attachment the side wall 82S of the sheath is formed with an enlarged bead or rim 100 about the edge thereof, so that this rim 100 may be clamped between the housing 12 and the mounting member 17 as an incident to the assembly of these parts. Thus, as will be evident in Figs. 1 and 3, the wall 14 and the flange 15 of the housing are so formed as to be joined by a relatively large radius corner, while the wall 95 and the flange 18 of the mounting member 17 meet in a relatively short radius corner, and when the mounting plate and the housing are assembled, this arrangement affords an annular space within which the annular rim 100 of the sheath may be positioned and clamped. The wall 95 and the wall 14 are so spaced in their opposed portions that the thin portion of the wall 82 S may be disposed therebetween, but this spacing is such that the rim 100 cannot pass therethrough. Hence, in the assembly operation, the sheath 82 is disposed with the rim 100 about the outer surface of the wall 95, and the housing 12 is then moved into position. This forces the rim 100 along the wall 95 and into contact with the flange 18, and the rim 100 is finally compressed between the external annular corner formed on the housing 12 and the internal annular corner afforded between the flange 18 and the wall 95. Such clamping of the rim 100 serves ordinarily to effect the desired sealed connection between the sheath 82 and the mounting plate 17, but if desired a suitable sealing means such as lacquer or the like may be applied therebetween prior to the assembly thereof. As shown in Figs. 1 to 6 the rim 100 is formed by rolling a predetermined portion of the rubber latex wall of the sheath soon after the removal of the forming mold from the latex, such portion of the wall being rolled on and along the surface of the mold toward the closed end of the sheath. This operation requires considerable skill in order to obtain the desired size in the roll or rim 100 while producing the required height in the side wall 82S, and if desired the rim may be formed as shown in Fig. 7 where an outwardly extended rim 100A is afforded on a sheath 82A by proper shaping of the mold and by trimming the excess material from the mold and from the bead 100A after such molding.

It has been pointed out hereinbefore that the wires 72 are extended from one of the windings of the transformer 56 to the terminals 57, and as will be evident in Figs. 1, 3 and 4 of the drawings, this involves extending the wires 72 from points located within the sheath 82 to points located outside of the sheath. While this might be accomplished by running the wires around the edge of the sheath, as defined by the rim 100, I prefer to extend the wires 72 directly through the sheath at points where the imperforate or sealed character of the sheath may readily be reestablished after passage of the wires 72 therethrough. Thus, as shown in Figs. 6 and 8, a pair of small tubular metallic rivets 102 are extended in spaced relation through the sheath 82, these rivets in the present case being located in the wall of the cavity 99, and small fibre washers 103 are disposed about the ends of the rivets 102 to protect the sheath against cutting by the flanged ends of the rivets. The wires 72 have flexible insulating sleeves thereabout which protect the major portion of their length, and the ends of the wires 72 which extend beyond such sheaths are passed through the rivets 102 as shown in Figs. 1, 5 and 8.

The openings through the rivets 102 and about the wires 72 are then closed by solder, as at 104, thereby to prevent passage of foreign substances through the rivets 102 and about the wires 72, and if desired, a coating of lacquer 105 may also be applied to the sheath about each wire 72 as additional assurance that the desired sealed relation has been established. The extended ends of the wires 72 are then enclosed for substantial distances by flexible insulating sleeves, and the extreme ends of the wires are soldered to the exposed ends of the terminals 57, as indicated at 106 in Fig. 4. The soldering of the wires 72 at the rivets 102 as well as the further sealing as at 105, and the soldering of the wires 72 to the terminals 57, are all performed before the housing 12 is placed in its final position about the electrical means, and hence, when the rim 100 of the sheath 82 has been sealed about the wall 95 by the clamping of the mounting member 17 and the housing 12, the complete protective sealing of the electrical means is assured.

When the electrical means of the transducer is thus sealed in accordance with this invention, the sheath 82 normally hugs relatively close to the exposed surfaces of the elements of the electrical means, as shown in Figs. 1, 2 and 3, and the walls of the cavities such as the cavities 97 and 99 extend into the corresponding recesses in the electrical means. The air which is trapped within the sheath 82 at the time of assembly of the transducer is, of course, at some pressure, such as sea level pressure, which corresponds to the atmospheric pressure at the assembly plant, and ample opportunity is afforded in the transducers of this invention for this trapped or enclosed air to expand and thereby reduce the forward pressure on the diaphragm as the transducer is transported to higher altitudes.

Such changes in external atmospheric pressure become effective upon the outside of the sheath 82 by passage of air through the restricted opening 90 so that such air flow is controlled and restricted, and because of this restricted and con-

trolled flow of air through the passage 90, the air within the back chamber of the transducer, and both inside and outside of the sheath, acts as a loading upon the diaphragm 20, and this loading action is varied in accordance with the external atmospheric pressure so as to avoid objectionable changes in desired response characteristics of the transducer. In the transducers of this invention, the air within the sealed chamber afforded by the sheath and the diaphragm may expand in a relatively great amount, for the sheath 82, by reason of its original shape, conforms quite closely to the external form of the electrical means and encloses a relatively small volume of air, and yet this sheath may expand, when required, so as to conform quite closely to the internal surfaces and form of the housing 14. Hence the available space within the housing and about the electrical means is utilized to substantially the maximum extent to enable maximum expansion of the air within the sheath.

In the embodiment of the invention shown in Figs. 1 to 8 of the drawings, the proportioning and relationship of the parts is such that the air trapped within the imperforate sheath 82 may expand to somewhat more than one and one-half times its original volume, so that absolute equalization of the air pressures on opposite faces of the diaphragm is attained up to altitudes of somewhat more than ten thousand feet. Thus the sealed transducer of this invention, as disclosed in Figs. 1 to 8 of the drawings, is such that its original frequency response curve and the output level thereof are maintained within permissible and relatively small limits of variation at altitudes up to and slightly above ten thousand feet; and it will be evident that by reducing the size of the electrical means and the sheath in relation to the internal volume of the housing, or by otherwise changing the proportional relation of the volume of trapped air with respect to the available expansion space within the housing, the altitude range of the transducer may be further increased.

Transducers of the character to which this invention relates may, however, often be used at altitudes as high as forty thousand feet, and it will be evident that absolute equalization of air pressures on opposite faces of the diaphragm in the embodiment shown in Figs. 1 to 8 would require an undue and excessive increase in the size of the housing 12 in order to afford space for the required expansion of the air within the sheath. In view of this, the present invention may be embodied in the form illustrated in Figs. 10 to 13 which show a transducer 10C that affords the desired protection for the electrical elements under those conditions where foreign substances and particularly water vapor may be encountered, and which enables full equalization of air pressure on the diaphragm, even at extreme altitudes. This desirable action is attained in this embodiment of the invention in such a way that the size of the transducer may be maintained at the minimum.

Thus, the transducer 10C embodies substantially the same elements and construction as the transducer 10 shown in Figs. 1 to 8, and corresponding elements or parts are identified by the same reference numerals. It may be observed, of course, that the diaphragm means may be afforded by a single diaphragm 20 or by cooperating diaphragms 20 and 20A such as those shown in Fig. 9. In this embodiment of the invention, however, a sheath 82C is utilized, and this sheath 82C has the same general form and construction as the sheath 82 or 82A and is associated with the other parts of the transducer in the same general manner as the sheath 82. Hence when the transducer 10C is initially assembled the sheath 82C embraces the electrical means in the manner illustrated with respect to the transducer 10 in Figs. 1 to 4 of the drawings.

In the embodiment of the invention shown in Figs. 10 to 13 the sheath 82C operates in the same manner as in the other embodiment to enable expansion and pressure equalization of the air trapped within the sheath, but in this embodiment means are provided whereby pressure equalization may be attained even after the full measure of distention has been attained in the sheath 82C. Such means are arranged to be air pressure responsive in such a way that the electrical means are fully sealed and protected at those low altitudes where objectionable foreign substances, and particularly water vapor or humidity, are likely to be encountered and at higher altitudes are effective to enable relatively free passage of air into or out of the space about the electrical means. Thus, at higher altitudes where low temperatures render the air moisture-free, the pressure equalization on the diaphragm is attained by relatively free flow of air into or out of the enclosure, while at lower altitudes where moisture or vapor may be present in the surrounding air, the desired pressure equalization is attained by expansion and contraction of the air trapped within the enclosure.

In affording such air pressure responsive means the stretchable characteristics of the sheath 82C are utilized, in the present instance, and to this end an occlusive opening or perforation 110 is formed in the sheath 82C as shown in Figs. 11 and 12, the location of this perforation being such that the surrounding material will be stretched in the course of distention of the sheath. Thus, as shown in Figs. 11 and 12 the occlusive perforation 110 is formed in the back wall of the sheath 82C so as to be opposite the panel 13C of the back wall 13 of the housing 12, for this portion of the sheath 82C is not stretched until the recess portions 97 and 99 of the sheath have been fully distended to the relation shown in Fig. 10 of the drawings. The perforation 110 is formed prior to assembly, and while the related portion of the sheath is stretched, so that when the sheath returns to its normal unstretched form, the perforation 110 is occluded or closed as shown in Fig. 11. Thus the portion of the sheath 82C in which the occlusive perforation 110 is formed provides a valve means which serves to open the perforation 110 when the sheath is stretched and to close the perforation when this portion of the sheath is unstretched. Hence, at low altitudes where dust, dirt or objectionable humidity are likely to be encountered, the perforation 110 remains closed as shown in Fig. 11, and the transducer is effectually protected against entry of such objectionable substances.

This closed or sealed relation is maintained as the altitude is increased, since the sheath may distend to the form shown in Fig. 10 without stretching of that portion of the sheath in which the perforation 110 is formed, and as a result the desired pressure equalization is attained at such altitudes while fully protecting the transducer against entry of foreign substances. After sufficient altitude has been attained to be beyond the zones wherein objectionable humidity or other foreign substances are present, the fur-

ther distention of the sheath 82C is attained by stretching of the sheath, and this results in opening of the perforation 110. When the perforation 110 is thus opened, the air within the sheath 82C may escape in an amount sufficient to substantially equalize with the external air pressure. Hence as higher altitudes are attained further air may escape from the sheath so as to thereby attain substantial equalization of air pressures on the opposite faces of the diaphragm. This action has been found to maintain the frequency response curve and the output level within relatively small limits of variation at altitudes as high as forty thousand feet above sea level.

When the air pressure within the sheath 82C has thus been materially reduced by use of the transducer at high altitudes, the subsequent descent to lower altitudes causes a substantial pressure differential to be applied to the exterior of the sheath 82C so that the sheath assumes the form shown in Fig. 13, the sheath being forced into all the recesses formed in the outer surfaces of the electrical means. Thus, after such an initial use of the transducer, the amount of air trapped within the sheath 82C is even less than when the transducer was originally assembled, and as a result, the occlusive opening 110 is maintained closed to even greater altitudes than in the first such use of the transducer.

However, it will be evident that in the descent from an extremely high altitude, it is necessary to allow return flow of air into the space within the sheath 82C in order to avoid the production of a differential pressure on the diaphragm 20 which would tend to force the diaphragm in an outward or forward direction. The valve means which is afforded by the sheath 82C and the perforation 110 are arranged in the present instance to accomplish this result, and it will be noted in this connection that the opening 110 is disposed so as to be opposite substantially the center of an enlarged opening 112 formed in the back member 46C of the magnetic yoke. Thus, after the sheath 82C has been drawn into contact with outer surfaces of the electrical means, as shown in Fig. 13 of the drawings, any further increase in the external air pressure will cause the portion of the sheath which is in opposed relation to the opening 112 to be forced inwardly to substantially the position shown in dotted outline in Fig. 11 of the drawings. This will, of course, cause the sheath to be stretched in that portion which overlies and is drawn into the opening 112, and as a result the perforation 110 will again be opened as indicated in Fig. 11, to thereby enable air to pass inwardly into the interior of the sheath 82C. In this manner the air pressure within the sheath 82C is equalized with the external air pressure as an incident to the descent from higher altitudes. If desired the opening 112 may be connected to space within the sheath by means such as a groove 114, Fig. 11, which extends along the inside face of the yoke member 46C and to a point beyond the outer edge of the magnet 52. Thus, even though the rear edges of the opening 112 may be sealed by virtue of the firm contact of the sheath with the face of the yoke 46C, the air entering through the opening 110 may pass through the slot or groove 114 and into the space within the sheath, thereby to equalize the air pressure. The arrangement is such that such opening of the perforation 110 does not take place after the transducer is brought to those altitudes where water vapor may be encountered, and hence the air within the sheath 82C is maintained dry at all times. In this connection it will be observed that the air which enters the sheath through the opening 110 will in every instance be air which has entered the housing 12 at a still higher altitude, so that this air will be quite dry and therefore unobjectionable. Hence, the pressures on the diaphragm 20 are equalized within permissible limits of variation in both ascent and descent of the transducer, and this is attained in such a manner that the transducer is protected against moisture as well as other objectionable substances.

Thus it will be apparent that the present invention enables the performance of radio communications systems to be materially improved in respect to aviation uses thereof, and this result is attained in a simple and effective manner. Moreover, it will be clear that the sealed transducers of this invention preserve intelligibility through the use of means which does not effect the acoustical characteristics in normal or sea level use, so that such transducers have an exceptionally wide range of use. The distensible sheath as utilized in the transducers of this invention also serves to protect the electrical means and the air gap of the transducers against dust, dirt and other foreign matter, thereby to insure proper operation of the transducers over long periods of use under adverse conditions. Moreover, the distensible character of the sheath insures that undue stresses will not be applied to the diaphragm by reason of high altitudes or concussion, and breaking of the diaphragm is thereby avoided.

Hence, while I have illustrated and described preferred embodiments of my invention, it is to be understood that these are capable of variation and modification and I therefore do not wish to be limited to the precise details set forth, but desire to avail myself of such changes and alterations as fall within the purview of the following claims:

I claim:

1. In a transducer, a cup-like housing, imperforate diaphragm means disposed in spanning relation to the open end of said cup-like housing, electrical means supported within said housing in spaced relation to at least certain of the internal surfaces thereof and operatively associated with said diaphragm means in transducing relation thereto, a cup-like stretchable member disposed within said housing in substantially spaced relation to at least certain of said surfaces and in a sealed relation to said diaphragm means to cooperate therewith in excluding water from said electrical means, said stretchable member having a normally closed perforation therein adapted to be opened upon predetermined stretching of said stretchable member.

2. In a transducer, imperforate diaphragm means, electrical means disposed on one side of said diaphragm means and operatively associated therewith in transducing relation, and means cooperating with said diaphragm means to afford a normally air tight enclosure about said electrical means and including normally closed pressure responsive valve means operable upon a predetermined reduction in the surrounding air pressure to enable air to flow into or out of said enclosure.

3. In a transducer, a cup-like housing, a waterproof diaphragm means disposed in spanning relation to the open end of said cup-like housing,

electrical means supported within said housing in spaced relation to at least certain of the internal surfaces thereof and operatively associated with said diaphragm means in transducing relation thereto, said electrical means embodying recesses in at least certain bordering side surfaces thereof, a cup-like stretchable member disposed within said housing in substantially spaced relation to at least certain of said surfaces and in a sealed waterproof relation to said diaphragm means to cooperate therewith in excluding water from said electrical means, said cup-like member having the walls thereof opposite said recesses formed to normally extend into said recesses, and said cup-like stretchable member having an occlusive, normally closed perforation formed therein in a position such that stretching of said cup-like member in the distention thereof acts to open said perforation after predetermined distention of said cup-like member.

4. In a transducer, imperforate diaphragm means, electrical means disposed in opposed relation to one face of said diaphragm means and operatively associated therewith in transducing relation, and means cooperating with said diaphragm means to afford a normally airtight enclosure about said electrical means and including stretchable means responsive to external air pressure so as to be stretched upon reduction of external air pressure and having an occlusive opening therein arranged to be opened by predetermined stretching of said stretchable means.

5. In a transducer, a cup-like housing, a waterproof diaphragm means disposed in spanning relation to the open end of said cup-like housing, electrical means supported within said housing in spaced relation to at least certain of the internal surfaces thereof and operatively associated with said diaphragm means in transducing relation thereto, said electrical means embodying recesses in at least certain bordering side surfaces thereof, a cup-like stretchable member disposed within said housing in substantially spaced relation to at least certain of said surfaces and in a sealed waterproof relation to said diaphragm means to cooperate therewith in excluding water from said electrical means, said cup-like member having the walls thereof opposite said recesses formed to normally extend into said recesses, and said cup-like stretchable member having an occlusive, normally closed perforation formed therein in a position such that stretching of said cup-like member in the distention or contraction thereof acts to open said perforation after predetermined stretching of said cup-like member.

6. In a transducer, imperforate diaphragm means, electrical means disposed in opposed relation to one face of said diaphragm means and operatively associated therewith in transducing relation, and means cooperating with said diaphragm means to afford a normally airtgiht enclosure about said electrical means and including stretchable means responsive to pressure differences between the internal and external air pressure so as to be stretched upon the application of a predetermined pressure difference and having an occlusive opening therein arranged to be opened by predetermined stretching of said stretchable means.

7. In a transducer, imperforate diaphragm means, electrical means disposed on one side of said dipahragm means and operatively associated therewith in transducing relation, and distensible means cooperating with said diaphragm means to afford a normally airtight distensible enclosure about said electrical means which may by its distension enable equalization of air pressures on said diaphragm means up to a predetermined altitude and including normally closed pressure responsive valve means operated by the reduction in the surrounding air pressure at said predetermined altitude to afford an opening in said enclosure through which air may flow into or out of said enclosure to equalize pressures on opposite sides of said diaphragm means at altitudes above said predetermined altitude.

8. In a transducer, imperforate diaphragm means, electrical means disposed in opposed relation to one face of said diaphragm means and operatively associated therewith in transducing relation, and air pressure responsive means cooperating with said diaphragm means to seal said electrical means against entry of foreign substances at sea level air pressures and to expose said electrical means and said one face of the diaphragm to the external air pressure when the transducer is transported above a predetermined altitude.

9. In a transducer, an imperforate flexible diaphragm means affording front and rear faces, electrical means disposed rearwardly of said rear face of said diaphragm means and operatively associated with said diaphrgam means in transducing relation therewith, walls providing a main housing surrounding said electrical means and affording substantial space between said electrical means and at least several of said walls, an internal housing member formed from thin stretchable material disposed within said main housing in a normally snug relationship to said electrical means and in spaced relation to the walls of said main housing, means associating said stretchable inner housing member with said diaphragm in a sealed relation to thereby afford a sealed enclosure for said electrical means, means providing a restricted air passage through said main housing to permit equalization of the air pressure between said housings with the outside air pressure and enable said stretchable inner housing to expand and contract as variations in external air pressure are encountered, said stretchable inner housing member having a normally closed perforation therein arranged to be opened upon predetermined stretching of said inner housing member.

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