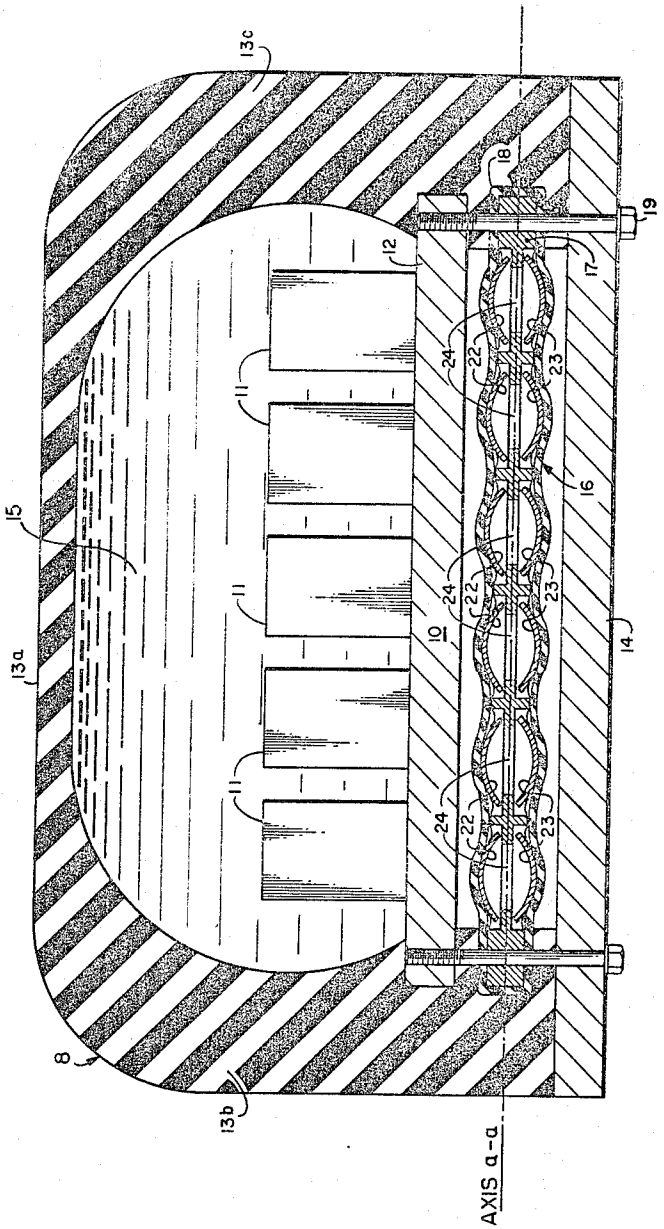
Oct. 4, 1966 C. L. BUCHANAN 3,277,434

TRANSDUCER PRESSURE RELEASE UNDER HIGH ENVIRONMENTAL PRESSURE

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FIG. 1



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FIG. 2

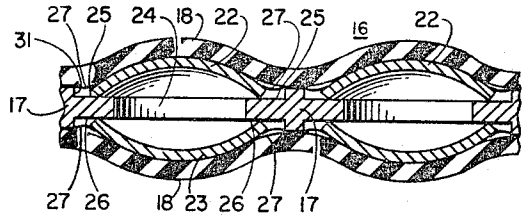


FIG. 3

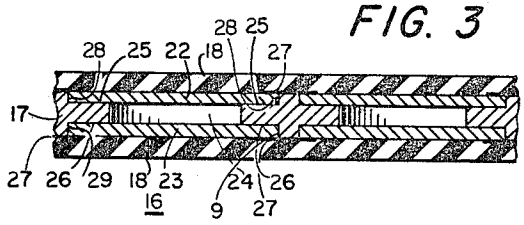
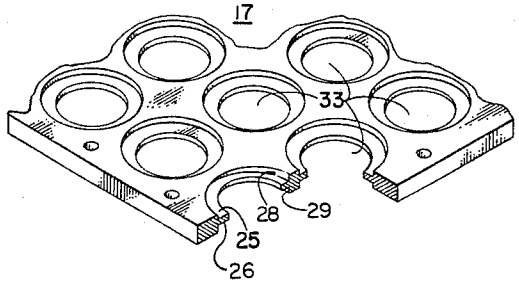


FIG. 4



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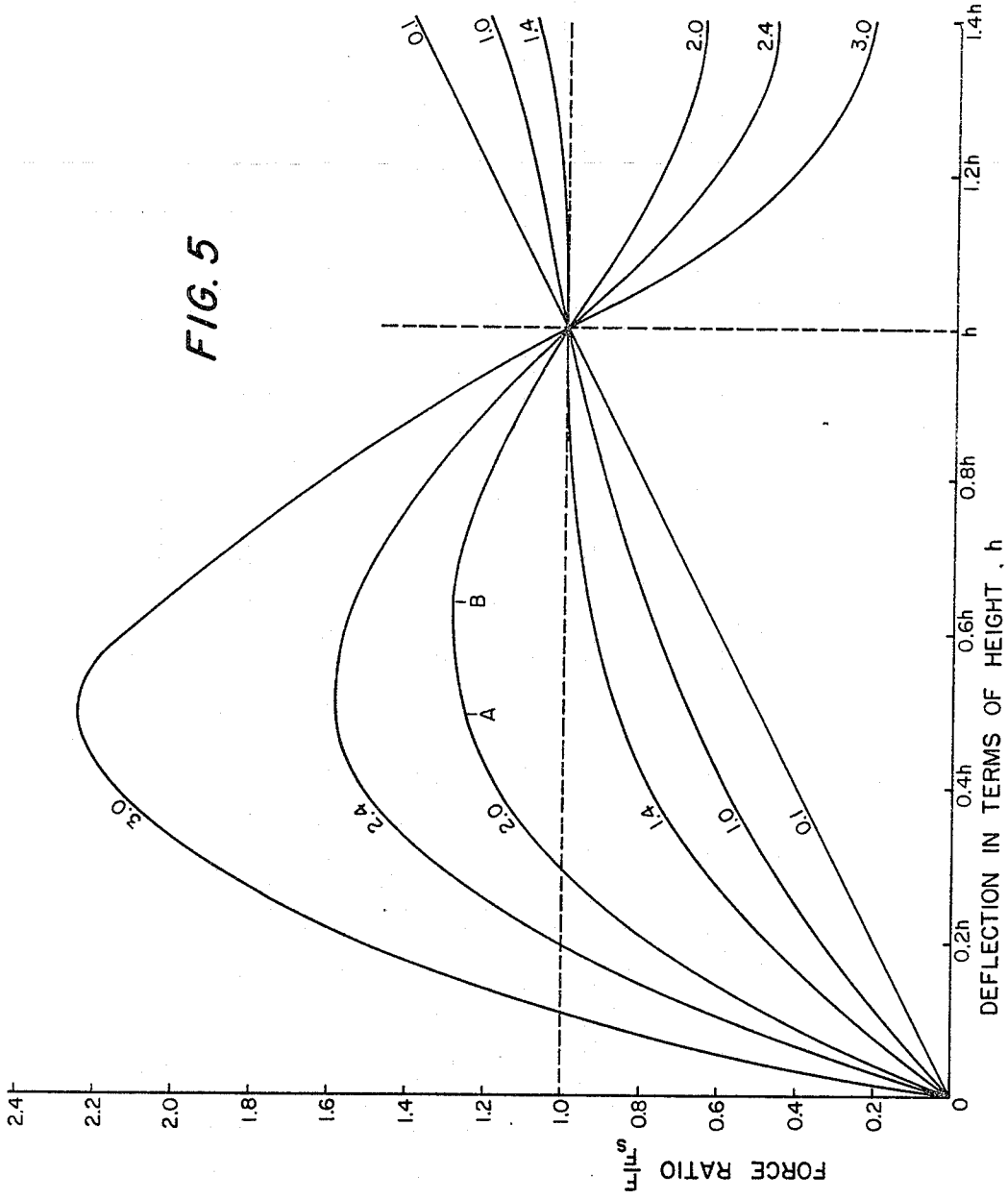
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FIG. 5



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3,277,434

TRANSDUCER PRESSURE RELEASE UNDER HIGH ENVIRONMENTAL PRESSURE

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Filed Aug. 3, 1965, Ser. No. 477,050
15 Claims. (Cl. 340—8)

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

The present invention relates to pressure release in electroacoustic transducers and more particularly to pressure release in electroacoustic transducers operating under large ambient pressure, such as when operating at great depths in sea water.

Pressure release is a standard design technique in the electroacoustic transducer art in that it significantly increases the efficiency of the transducer. Conventionally, pressure release is obtained by maintaining a medium having a low acoustic impedance relative to the acoustic impedance of the environment in which the transducer is to be used close to the radiating surface of the transducer from which it is desired to suppress radiation. When the compressional waves produced by the motion of the radiating surface strike this low acoustic impedance medium, they are reflected. In the instance where the radiating surface with which the low acoustic impedance is maintained in close position is opposed to the desired direction of radiation from the transducer, the waves reflected from the low acoustic impedance medium add to the compressional waves traveling in the desired direction and thus increase the efficiency of the transducer.

Air is a medium conventionally used to obtain pressure release in underwater electroacoustic transducers. Many ways are known to maintain the air in close relationship with the radiating surface from which it is desired to suppress compressional waves. Among these are maintaining an air filled, water tight chamber in contact with the surface or cementing a material which contains many air cells, such as foam rubber or foam plastic, to the surface. These prove to be satisfactory when the ambient hydrostatic pressure is relatively low and where the transducer is operating at a relatively high frequency.

Recently, however, it has become desirable to have transducers operating at low frequencies and at great depths. Under such conditions, conventional pressure release materials are not satisfactory. Foam rubber and foam plastic collapse under the hydrostatic pressure which may be equal to more than 1000 atmospheres of pressure. Also the pressure release capability of air under such pressure is materially decreased, if not eliminated, since the density of the air approaches that of the sea water environment. Thus, the transducer designer has been deprived of the ability to use the standard design technique of pressure release in transducers designed to operate at great depths. This has meant that other techniques have had to be used in place of pressure release techniques and as a result thereof, the size, complexity and cost of such transducers has been increased when compared with those of transducers operating at lesser depths and yet the efficiency of available deep transducers is no greater than that of transducers wherein pressure release techniques can be used.

The present invention overcomes the aforedescribed disadvantages by making pressure release techniques available in transducers designed to operate under large hydrostatic pressures. To do so, the instant invention contemplates a plurality of air-tight, air-filled conical disc springs spaced as close as possible to one another and held in close relationship to the radiating surface from

which it is desired to suppress radiation. Advantage is taken of the characteristic of such a spring that a relatively large amount of force is needed to deflect it up to a certain percent of its height and, thereafter, the applied force does not have to be increased very much to deflect it further.

The strength of the material, typically steel, of which the springs are composed is chosen so that the force applied thereto by the ambient hydrostatic pressure at the depth at which the transducer is to be used will be just sufficient to deflect the springs the percent of their height where further small increases in applied force will cause significant further deflection. Then, the small increases in applied force caused by compressional waves emanating from the surface from which it is desired to suppress radiation striking the springs can thus cause further deflection. The height to thickness ratio of the springs is chosen so that the distance the springs travel in being further deflected by the small increase in applied force caused by the compressional waves striking them is approximately equal to the distance the surface travels in producing such waves thereby causing such waves to be suppressed.

An object of the present invention is the provision of novel pressure release means in a transducer.

Another object is to provide a relatively efficient, inexpensive, and simple transducer suitable for use under large ambient pressure.

A further object of the invention is the provision of pressure release in a transducer suitable for operation at great depths.

Still another object of this invention is to provide pressure release in a relatively inexpensive and simple, low frequency transducer suitable for use under large ambient hydrostatic pressure.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings in which like reference numerals designate like parts throughout the figures thereof and wherein:

FIG. 1 shows a cross section of a transducer employing pressure release means according to the present invention;

FIG. 2 illustrates, in cross section, the pressure release means of the invention in non-pressurized condition;

FIG. 3 is a cross sectional view of the pressure release means of the instant invention under operating pressure condition;

FIG. 4 illustrates a perspective view with a broken section of a portion of the separating plate; and

FIG. 5 illustrates the force vs. deflection curves of conical disc springs having height to thickness ratios varying from 0.1 to 3.0.

It should be noted that FIG. 1 is similar in general detail to FIG. 1 of the patent to R. L. Steinberger, Patent No. 2,906,993. However, this similarity should not be construed to be an admission as to the pertinence of Steinberger to the inventive concept of the present invention. Unlike Steinberger, the present invention contemplates obtaining pressure release by maintaining the low acoustic impedance under only slight pressure compared to that of the environment by enclosing it within a spring-like enclosure having a unique characteristic as will become clearer hereinafter. In this way, it is possible to obtain pressure release in transducers operating under large environmental pressures.

Furthermore, it should be noted that the present inventive concept is not limited to use in transducers such as shown in FIG. 1 since it could be used anywhere where it was desired to obtain pressure release.

Referring now to the details of FIGURE 1, the transducer 8 shown comprises an electroacoustic vibrating element, generally indicated as 10, consisting of an array of crystals 11 cemented to a backing plate 12. The crystals are energized by suitable electrical connections (not shown) in a conventional manner. The front and sides of the vibrating element are sealed from the environment in which the transducer is to be used by front wall 13*a* and side walls 13*b* and 13*c* which are formed of a flexible, fluid-impermeable material such as rubber. The rear of the vibrating element is sealed from the environment by mounting plate 14. In operation, compressible waves emanate from vibrating element 10 in at least two directions; namely toward front wall 13*a* and toward mounting plate 14.

The space between the vibrating element and front and side walls is filled with a fluid 15 which furnishes an impedance match between the crystals and the environment in which the transducer is to be used and also acoustic coupling between the crystals and the flexible walls. Front wall portion 13*a* is significantly thinner than side wall portions 13*b* and 13*c* and thus vibrates with much greater amplitude than the side walls in response to the compressional waves traveling through the fluid 15 and, consequently, is primarily responsible for creating compressional waves in the environment in which the transducer is used.

The pressure release means, denoted generally as 16 and which is described in more detail in conjunction with the description of FIGS. 2 and 3, is secured in a cavity between backing plate 12 and mounting plate 14 and carried on a separating plate 17 which has a longitudinal axis *a*—*a* and a plurality of chambers 24 formed thereon, separating plate 17 is described in more detail in conjunction with the description of FIG. 4. Chambers 24 are spaced as close to one another as possible on the separating plate 17 to provide maximum pressure release. The encasement for the pressure release means 16 is a flexible, fluid-tight coating 18 which is typically rubber, though not limited thereto. The backing plate 12 and separating plate 17 are secured to the mounting plate 14 by bolts 19 which are spaced at regular intervals around the periphery of the mounting plate. In practice, the axis *a*—*a* of separating plate 17 is preferably maintained within a distance from backing plate 12 of less than approximately ⅛ of a wavelength of the operating frequency of the transducer so that the back radiation reflected from the pressure release means is in phase with the front radiation and thus will additively combine with such front radiation.

Considering FIG. 1 in conjunction with FIG. 2, wherein the pressure release means 16 of the instant invention is shown in enlarged cross section as it would appear without the application of the ambient pressure of the environment in which the transducer is to be used, the pressure release means 16 comprises a plurality of elastic members 22, which may be in the form of a conical disc spring, such as a Belleville spring, with its apex disposed toward the backing plate 12 and away from separating plate 17 (FIG. 1), a plurality of lower complementary members 23, and a chamber 24 formed between each complementary upper and lower member. Each chamber 24 is filled with a compressible medium having a low acoustic impedance relative to the acoustic impedance of the environment in which the transducer is to be used. When, as is the usual case, the transducer is to be used in water, chamber 24 may use air as the medium. The lower member 23 is shown to be a conical disc spring with its apex disposed away from backing plate 12 and toward separating plate 17 (FIG. 1). However, it should be understood that the geometrical configuration and material of which lower member 23 is composed are limited only by the requirement that the percent volume decrease of chamber 24 not be so large under operating conditions that the density of the medium filling chamber 24 will be raised to the point where its acoustic impedance will approach that of the environment.

The peripheries of the upper and lower members 22 and 23 are respectively held in slideable contact with opposed rims around chamber 24 formed by recessed surfaces 25 and 26, more clearly shown in FIG. 4, of separating plate 17. The purpose of maintaining the peripheries of members 22 and 23 spaced from one another is to allow members 22 and 23 to be deflected past center as is desirable in many instances when the transducer is operating in its intended environment.

Flexible, fluid-tight seal 18 covers the upper and lower members of the pressure release means and the separating plate 17 and prevents any fluid communication to or from chambers 24. Spring clips 27 urge the upper and lower members against the recessed surfaces of separating plate 17 and prevent such members from becoming misaligned.

FIG. 3 illustrates, in cross section, the pressure release means when the upper and lower members, 22 and 23 respectively, are both conical disc springs having a height to thickness ratio of approximately 1.4 and are subjected to ambient pressure conditions of the environment in which the transducer is to be used. It should be understood that the illustration of the pressure release means, when composed of opposed conical disc springs having height to thickness ratios of approximately 1.4, is merely by way of example and not to be construed as a limitation on the scope of this invention.

The recessed surfaces 25 and 26 of separating plate 17 are preferably annular with a diameter equal to the diameter of the conical disc springs when they are deflected 100 percent of their height. Then, the conical disc springs will firmly abut sidewalls 28 and 29 respectively under operating conditions. Sidewalls 28 and 29 preferably have heights equal to the thickness of the springs used.

The purpose of separating plate 17 can now be better understood with reference to FIG. 5. As can be seen from FIG. 5, when conical disc springs 22 and 23, having height to thickness ratios of approximately 1.4, are deflected 100 percent of their height, further small increases in applied force will cause the springs to deflect further or, in other words, past center. If separating plate 17 were not used, the springs would be in contact with one another and thus, the pressure release means would no longer be able to provide pressure release. Furthermore, the springs would be unable to respond with further deflection to the small increases in applied force caused by the compressional waves striking them.

Flexible fluid-tight seal 18 continues to prevent fluid communication to or from chambers 24 and spring clips 27 continue to urge the upper and lower members, 22 and 23 respectively, against recessed surfaces 25 and 26 respectively.

FIG. 4 illustrates a portion of a separating plate 17 suitable for use with conical disc springs having height to thickness ratios of approximately 1.4. The plate has a plurality of apertures 33 therethrough surrounded by opposed annular surfaces that are respectively recessed from the opposed surfaces of plate 17 and joined to such surfaces of plate 17 by vertical walls. As explained above, the edge of the conical disc spring 22 forming the upper member of the pressure release means is held in slideable contact with the annular recessed surface 25 and the edge of the conical disc spring 23 forming the lower member of the pressure release means is held in slideable contact with the annular recessed surface 26. Apertures 33 are preferably spaced as close as possible to one another giving due consideration to the maintenance of sufficient strength so that plate 17 will not buckle when subjected to the forces applied during operation of the transducer. The outer diameters of surfaces 25 and 26 are preferably equal to the diameter of the conical disc springs held in slideable contact therewith when deflected

100 percent of their height and the vertical walls **28** and **29** have a height preferably equal to the thickness of the respective springs.

FIG. 5 shows known force deflection curves for conical disc springs of different height to thickness ratios. The curves are shown in terms of the ratio of the force applied to the force necessary to deflect the spring 100 percent of its height, F/F_s, vs. deflection in terms of height, h, to normalize them for springs having different strengths. As can be seen from FIG. 5, the slope of the force vs. deflection curves for springs having height to thickness ratios of greater than 0.1 is relatively large for a first portion of the curve and, thereafter, is relatively small for a second portion of such curve. The curve for a spring having a height to thickness ratio of 2.0 is typical. This curve has a first portion OA having a relatively large slope and a second portion AB having a relatively small slope. For this particular curve, if the spring is deflected to point A by the quiescent force applied, an increase in applied force approximately equal to 2.5 percent larger than the force applied under quiescent conditions will cause a deflection approximately 17 percent larger than the force applied under quiescent conditions. Thus, it is clear that the spring can absorb relatively large amounts of applied force with relatively small deflection and then provide significant further deflection in response to relatively small increases in applied force. Consequently, the springs are suitable for use in pressure release means for transducers including those operating at great depths since the spring can absorb the force applied by the environment, which is relatively large, with relatively small deflection and yet provide relatively large deflection in response to further relatively small increases in applied force.

Using these curves and having determined, by conventional methods, how much quiescent force will be applied to the springs when operating at the desired depth, the force necessary to deflect the spring 100 percent of its height, the distance of movement of the surface producing the compressional waves that it is desired to suppress, and the change in applied force that will be caused by such compressional waves striking the spring, one may choose springs composed of the proper strength material and of the proper height to thickness ratio to deflect when struck by compressional waves an amount approximately equal to the movement of the surface producing the waves.

Sometimes it is desirable to have different parts of the transducer array vibrate at different amplitudes. Maximum pressure release for such an array can be obtained by separately determining the force applied to each of the conical disc springs when struck by the compressional waves produced and then choosing the strength of the material and height to thickness ratio for the particular spring with reference to such force so that the deflection caused by the application of the particular force will be approximately equal to the movement of the vibrating surface causing the force.

Thus, it can be seen that the instant invention provides pressure release in transducers in a novel manner which is effective at great sea depths and which is inexpensive and simple.

Obviously many modifications and variations of the present invention are possible in light of the above teachings. It is therefore to be understood, that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described.

What is claimed and desired to be secured by letters patent of the United States is:

1. Pressure release means for use in conjunction with compressional wave producing vibrating elements comprising:

a separating plate having first and second faces, a plurality of apertures therethrough between said first and second faces, and a longitudinal axis parallel to said first and second faces;

a conical disc spring extending over each of said apertures;

a complementary member extending under each of said apertures and disposed opposedly to its respective conical disc spring to form a chamber within each of said apertures between said conical disc springs and their respective complementary members;

a compressible medium filling each of said chambers; and

a flexible, fluid impermeable seal enclosing said conical disc springs, complementary members, and separating plate.

2. The pressure release means of claim **1** wherein said first face has annular recessed surfaces about each of said apertures upon which said conical disc springs slidably rest.

3. The pressure release means of claim **1** wherein each of said complementary members is a conical disc spring having its apex disposed away from said plate.

4. An acoustic transducer including the pressure release means of claim **1** and further comprising a vibrating element for producing compressional waves in at least two directions and said longitudinal axis being spaced from said element transverse to one of said directions.

5. The transducer of claim **4** wherein said first face has annular recessed surfaces about each of said apertures upon which said conical disc springs slidably rest and said longitudinal axis is spaced from said vibrating element a distance equal to less than ⅛ of the wavelength of the compressional waves emanating from said element.

6. The transducer of claim **5** wherein said complementary members are conical disc springs and said second face has annular recessed surfaces about each of said apertures upon which said conical disc springs slidably rest.

7. In a transducer for use in an environment characterized by an environmental acoustic impedance and pressure, the combination comprising:

a vibrating element having compressional waves emanating therefrom in at least two directions; and

pressure release means operatively associated with said vibrating element and disposed transversely to one of said directions to suppress compressional waves traveling in said one direction;

said pressure release means including:

an elastic upper member disposed for deflection away from said vibrating element upon being struck by compressional waves emanating from said element;

a lower complementary member disposed opposed to said upper member to form a chamber therebetween;

a flexible fluid-impermeable seal enclosing said upper and lower members;

a compressible medium filling said chamber, said medium having an acoustic impedance less than said environmental acoustic impedance whereby there is an acoustic impedance mismatch between said chamber and said environment;

said upper member having a force vs. deflection characteristic such that the percent deflection increase is larger than the percent applied force increase when said transducer is placed in said environment and said upper member is struck by a compressional wave emanating from said element.

8. The transducer of claim **7** wherein under operating conditions, said upper member of said pressure release means is displaced from said vibrating element at its greatest distance therefrom a distance equal to less than ⅛ of the wavelength of the compressional waves emanating from said element.

9. The transducer of claim 8 wherein said upper member of said pressure release means is a conical disc spring with its apex disposed toward said vibrating element.

10. In an electroacoustic transducer for use in an environment characterized by an environmental acoustic impedance and pressure, the combination comprising:

a vibrating element having compressional waves emanating therefrom in at least two directions;

a separating plate having a longitudinal axis spaced from said element transverse to one of said directions and having a plurality of apertures therethrough with a respective pressure release means supported thereabout;

each of said pressure release means having an elastic upper member disposed on a first side of said plate for deflection away from said vibrating element upon being struck by a compressional wave emanating from said element and a complementary second member disposed on a second side of said plate and aligned with said first member in said one of said directions to form a chamber therebetween, said upper member having a force-deflection characteristic such that the percent deflection change is greater than the percent applied force change when said transducer is operating in said environment and said upper member is struck by said compressional wave;

a compressible medium filling each of said chambers, said medium having an acoustic impedance less than said environmental acoustic impedance whereby an acoustic impedance mismatch exists between said medium and said environment and compressional waves striking said upper member will be reflected, and

a flexible fluid-impermeable seal enclosing said upper and lower members and said plate.

11. The transducer of claim 10 wherein said longitudinal axis is spaced from said vibrating element a distance equal to less than ⅛ of the wavelength of the compressional waves emanating from said element.

12. The transducer of claim 11 wherein each of said upper member is a conical disc spring with its apex disposed toward said vibrating element.

13. The transducer of claim 12 wherein said plate has annular recessed surfaces on said first side about each of said apertures and said conical disc springs contact said plate on said recessed surfaces.

14. The transducer of claim 13 wherein each of said lower members is a conical disc spring with its apex disposed away from said vibrating element and said plate has annular recessed surfaces about each of said apertures wherein said springs contact said plate.

15. The transducer of claim 14 wherein said environment is water and said medium is air.

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