

[54] **ELECTROSTATIC TRANSDUCER WITH
VENTED DIAPHRAGM**
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[51] Int. Cl. H04r 19/04
[58] Field of Search 179/111, 180; 29/594, 447,
29/448

[56] **References Cited**

UNITED STATES PATENTS
2,868,894 1/1959 Schultz 179/111

3,418,437 12/1968 Hoffmann 179/180
3,076,870 2/1963 Jones, Jr. 179/111

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[57] **ABSTRACT**

An acoustic pressure transducer wherein a thin metallic diaphragm is mounted in close proximity to a backplate and electrically insulated therefrom to form a capacitor which is variable in capacity in response to variations in acoustical pressure, and at least one capillary aperture is effected through the diaphragm to thereby reduce differentials in static air pressure on opposite sides of the diaphragm.

10 Claims, 14 Drawing Figures

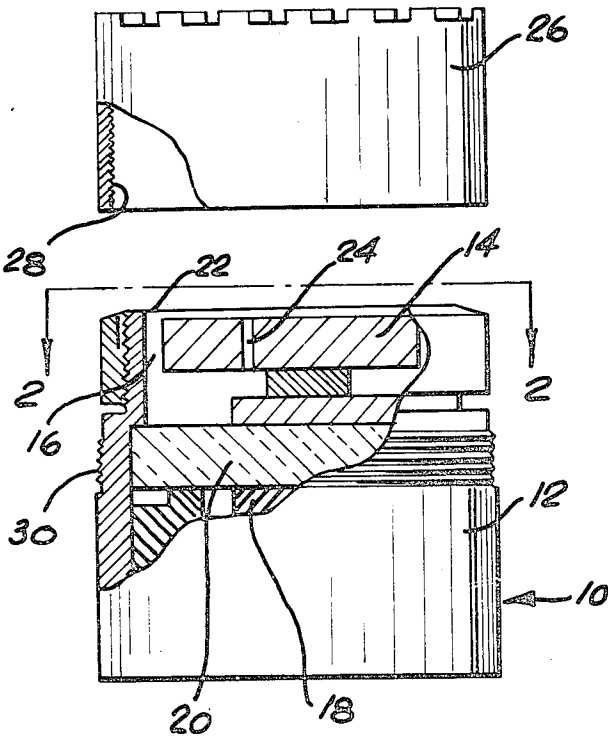


Fig-1

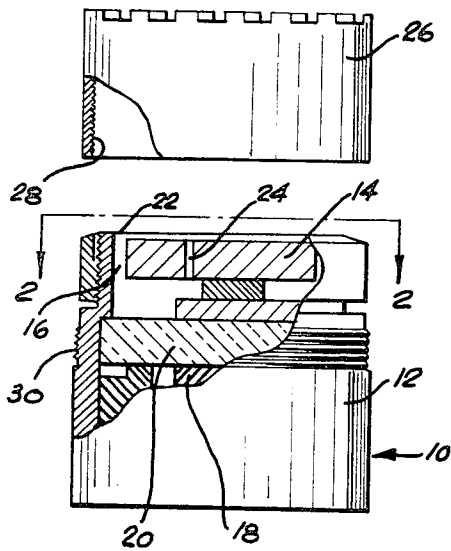


Fig 3A

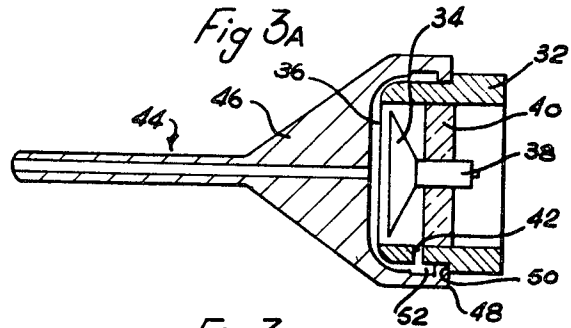


Fig 3B

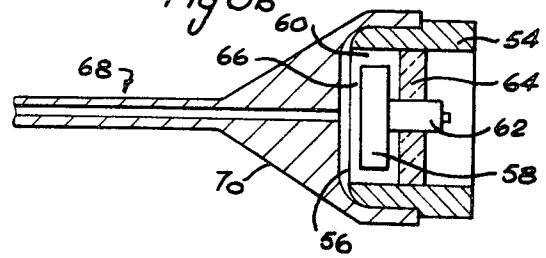


Fig-2

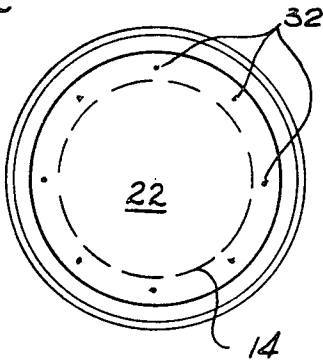


Fig 4

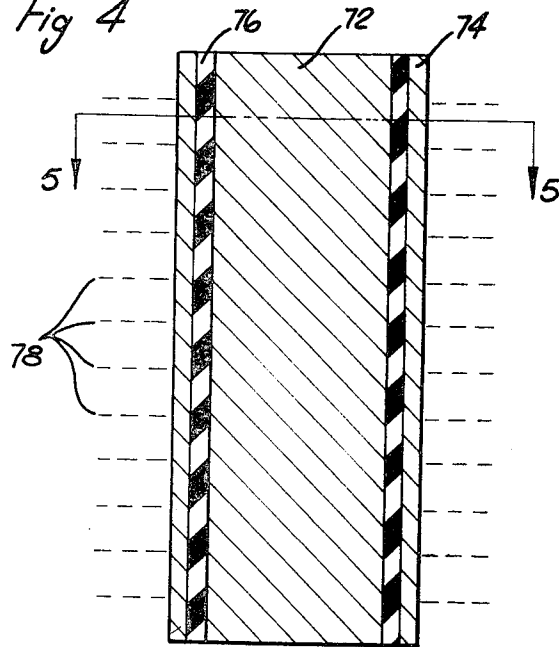
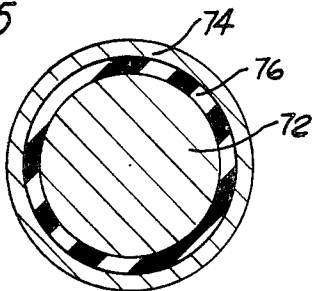
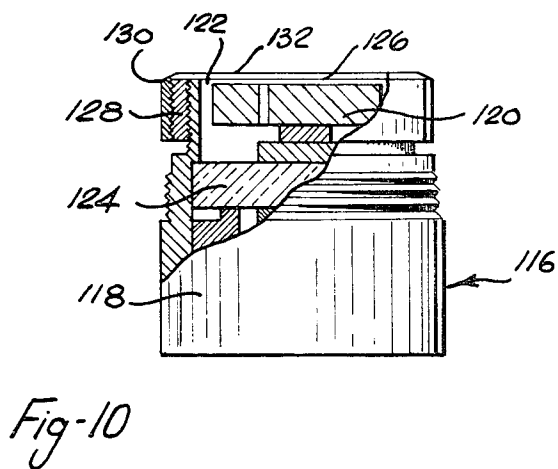
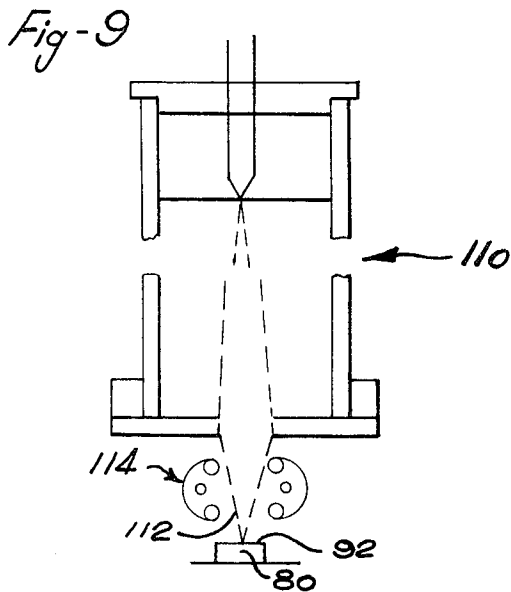
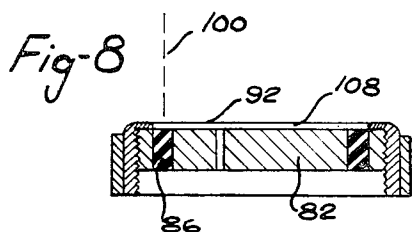
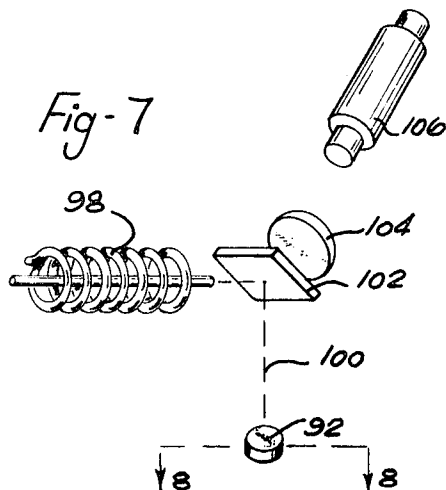
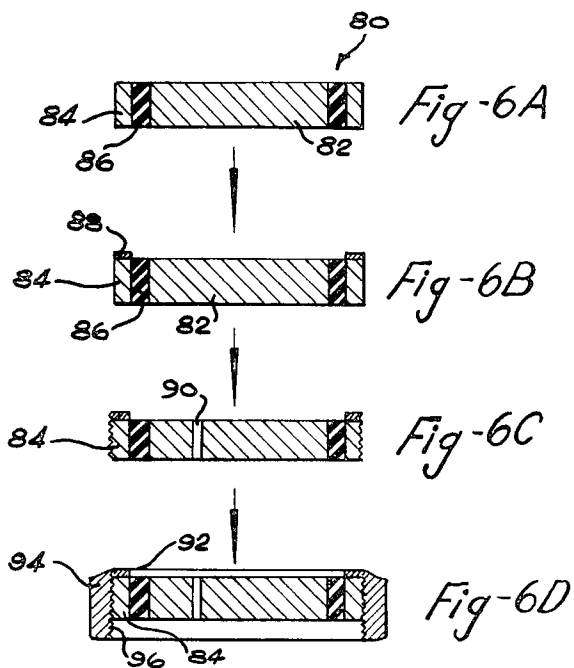


Fig-5



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ELECTROSTATIC TRANSDUCER WITH VENTED DIAPHRAGM

BACKGROUND OF THE INVENTION

1. Field of the Invention

The field of art to which the invention pertains includes the field of transducers, particularly pressure-sensitive diaphragms.

2. Description of the Prior Art

The transducers with which this application most directly relates are of the condenser microphone type wherein a thin metallic diaphragm is mounted in close proximity to a rigid backplate. The diaphragm and backplate are electrically insulated from each other and constitute the electrodes of a capacitor. When the microphone is exposed to sound or other dynamic pressure, the diaphragm is submitted to an alternating force proportional to the pressure and the diaphragm area. The consequent movement of the diaphragm varies the capacity and these variations are transduced into an AC-voltage component when a constant charge is present between the electrodes. Wide linear frequency ranges are obtained by damping the diaphragm resonance with appropriate holes in the backplate and by adjusting the spacing and the tension of the diaphragm. Toward the low frequencies, the response of the cartridge is only affected by the influence of the pressure-equalizing arrangement. This arrangement consists of a capillary leakage hole through which equalization of static air pressure on both sides of the diaphragm is obtained at a suitable rate. The pressure-equalization hole is designed to minimize the influence of ambient pressure or altitude variations on the microphone sensitivity. Typically, the equalization hole is defined by a complex vent path through the rear sensor assembly. It must be accurately placed and defined, resulting in high manufacturing costs. When a coupling component, such as a probe, is utilized with the microphone, the component design must be carefully coordinated with that of the microphone, and its manufacture controlled to within very close tolerances so as to prevent blockage of the equalization hole. Furthermore, the vent function can become completely blocked if the equalization hole becomes plugged by dirt or other material.

SUMMARY OF THE INVENTION

The present invention provides an acoustic pressure transducer of the type utilizing a thin metallic diaphragm and a backplate, but wherein the afore-noted static pressure equalization hole can be eliminated by the utilization of capillary vent apertures through the diaphragm. In the present invention, the diaphragm defines at least one such capillary vent aperture whereby differentials in static air pressure on opposite sides of the diaphragm are reduced. In specific terms, a transducer is provided comprising a thin metallic sensing diaphragm, a backplate, and means spacing the diaphragm in close proximity to the backplate so as to form a capacitor therewith which is variable in capacity in response to variations in acoustic pressure, the diaphragm defining at least one of the aforementioned capillary vent apertures. The transducer includes a housing and means electrically insulating the housing from the backplate. By utilization of this invention, the diaphragm, housing and insulating means form a closed chamber except for the diaphragm apertures.

To form the transducer, the components are mounted and the diaphragm is subjected to a narrow beam of energy of sufficient intensity to pierce it, e.g., as from a laser (or maser), electron beam source, or the like. The apertures serve to improve the low frequency response. After forming one or more apertures, the low frequency response of the transducer can be determined and compared to a desired response. One or more additional vent apertures can then be formed to thereby more closely approach the desired response.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an elevational, partly cross-sectional view of a microphone cartridge constructed in accordance with this invention;

FIG. 2 is a plan view of the microphone diaphragm utilized herein, taken on the line 2—2 of FIG. 1, in the direction of the arrows;

FIGS. 3A and 3B are schematic, cross-sectional views of a prior art microphone and a microphone of this invention, respectively, with probe attachments thereon;

FIG. 4 is a schematic, cross-sectional view of a structure utilized in the manufacture of a plurality of microphone cartridges;

FIG. 5 is a cross-sectional view taken on the line 5—5 in FIG. 4, in the direction of the arrows;

FIGS. 6A—D are cross-sectional views depicting the assembly of microphone components constructed in accordance with this invention;

FIG. 7 is a schematic, perspective view of a laser being utilized in accordance with this invention;

FIG. 8 is a schematic, cross-sectional view of a microphone component of this invention during vent formation;

FIG. 9 is a schematic, cross-sectional view of a source of electron beams being utilized in accordance with this invention; and

FIG. 10 is an elevational, partly cross-sectional view of a microphone cartridge incorporating an acoustic pressure filter constructed in accordance with this invention.

DETAILED DESCRIPTION

Referring to FIG. 1, a condenser microphone 10 is shown constructed in accordance with this invention. A housing 12 encloses a backplate 14 which is spaced from the housing as indicated at 16. As is known to the art, an output terminal 18 is connected to the backplate 14 and additionally supported within the housing 12 by means of an insulating quartz or glass disk 20. A thin, metallic pressure-sensitive diaphragm 22 is mounted, as described in more detail hereinafter, in close adjacent proximity to the backplate 14, but is separated therefrom so as to form a variable capacitor with the entire front surface of the backplate; the diaphragm 22 and backplate 14 constitute electrodes of the capacitor. With a charge present between the electrodes e.g., as obtained by means of a stabilized DC-polarization voltage as known to the art, the capacitor varies in electrical capacity in response to dynamic pressure variations. In this manner, when the microphone 10 is exposed to dynamic pressure, such as from sound, the diaphragm 22 is subjected to an alternating force proportional to the pressure and the diaphragm area. The consequent movement of the diaphragm 22 varies the capacity, and these variations are transduced into an AC-voltage component.

Damping of the diaphragm resonance (so as to increase high frequency response) is controlled by means of appropriate holes, such as at 24, in the backplate 14 and by adjusting the tension of the diaphragm and its spacing from the backplate, as known to the art. A protecting grid 26 is provided with internal threads 28 for threadably securing the grid to mating threads 30 on the microphone head.

Towards the low frequencies, the response of the cartridge is only affected by the influence of the pressure equalizing arrangement. In prior art devices, as will be illustrated hereinafter, this arrangement consists of a capillary leakage hole through the microphone housing so that equalization of static air pressure on both sides of the diaphragm is obtained. However, in the present structure, no provision need be made for such a leakage hole through the housing. Instead, and referring to FIG. 2, a plurality of capillary vent apertures 32 are formed through the diaphragm 22. The diaphragm 22 is typically about 4 microns in thickness and the capillary vent apertures 32 are generally from about 2 to about 30 microns in diameter. The vent apertures 32 perform the function of the

prior art capillary leakage hole in that they allow equalization of the static air pressure on both sides of the diaphragm so as to improve low frequency sensitivity. By such means, one can select a particular sensitivity level for the microphone at a predetermined frequency, measure the response of the microphone at the beginning and after the formation of each of the apertures 32, until the desired sensitivity has been obtained. The apertures are formed by means of high intensity beams of energy, as will be amplified on hereinafter. Since the spacing between the diaphragm 22 and the backplate 14 is quite close, the apertures 32 are formed around the outer periphery of the diaphragm 22, above the spacing 16, so as to preclude welding of the diaphragm to the backplate. Referring again to FIG. 1, it will be seen that the diaphragm 22, housing 12 and insulating means 20 form a closed chamber except for the capillary vent apertures 32.

Referring to FIGS. 3A and 3B, microphones constructed in accordance with the present invention (FIG. 3B) and in accordance with the prior art (FIG. 3A) are schematically depicted for ready comparison of the structures and to illustrate the advantages obtained by the novel construction herein. The prior art structure of FIG. 3A includes a housing 32, a backplate 34, a diaphragm 36 stretched across the housing and in close proximity to the backplate 34, an output terminal 38 for the backplate and an insulator 40 supporting the output terminal 38 and backplate 34. A capillary leakage hole 42 is formed in the housing between the insulator 40 and backplate 34 so as to vent the chamber 43 formed by the housing 32 insulator 40 and diaphragm 36. The microphone of FIG. 3A is depicted utilized with a probe 44 which has a base 46 that is formed to thread onto the housing 32 until the lower edge 48 thereof abuts a collar 50 on the microphone housing 32. The probe base 46 is internally shaped so as to provide a channel 52 adjacent the capillary leakage hole 42 to provide an airpath therefrom through the probe, to allow airflow into the chamber 43. It will be seen that the components have to be very carefully sized so that the channel 52 is properly aligned with the capillary leakage hole 42, and the probe 44 must be maintained free from particles which might clog the leakage hole. In this regard, it should be noted that the drawing in FIG. 3A is only schematic and that the sizing of the leakage hole 42 is much smaller and generally follows a more complex path through the housing than as indicated.

The present construction is depicted schematically in FIG. 3B illustrating a housing 54 across one end of which is stretched a diaphragm 56 in close proximity to a backplate 58 which is spaced from the housing as indicated at 60, all as previously described with respect to FIG. 1. Here too, the output terminal 62 is supported by an insulator disk 64. In this case, a chamber 66 is defined by the housing 54, insulator disk 64 and diaphragm 56 and is completely closed except for communication by means of the capillary vent apertures, in the manner illustrated in FIG. 2. As a result of this construction, a probe 68 can be provided having a much simplified base 70 structure so that the probe need merely be threaded onto the front end of the microphone, without regard to the alignment of vent paths. By providing a plurality of capillary vent apertures, redundancy of venting is obtained so that if a particular aperture were to be plugged, other apertures would still function to vent the microphone.

A further advantage is realized by the utilization of diaphragm vent apertures as herein provided, and that is that the construction of microphone cartridges can be readily adapted to unique mass-production procedures, as illustrated in FIGS. 4-6. Referring specifically to FIGS. 4 and 5 a solid metallic cylinder 72 is provided surrounded by a metallic tubular member 74 which is adhered to the solid cylinder 72 by means of a layer of electrically insulating material 76, such as epoxy. The resultant assembly is then cut transverse to its longitudinal axis as indicated by the dashed lines at 78, to yield a component 80 as illustrated in FIG. 6A. Referring to FIGS. 6A-D, the component 80 comprises a metallic backplate 82 separated from an outer metallic ring 84 by the epoxy or other

electrically insulating coating 86. As a next step in production, illustrated in FIG. 6B, the outer ring 84 is electroplated on one surface thereof as indicated at 88 by any well-known method, to obtain a desired spacing between the top of the electroplated ring and the top surface of the backplate 82, which desired spacing will correspond to the capacitive electrode separation when the diaphragm is in place.

Referring to FIG. 6C, a pattern of openings, such as shown at 90, are formed by chemical milling, machining, or the like to obtain an appropriate pattern of openings for high frequency response, as discussed above with respect to FIG. 1. The outer ring 84 is also threaded so as to be able to receive the diaphragm thereon. Referring to FIG. 6D, the diaphragm 92 is carried by a ring member 94 which is internally threaded at 96 so as to engage the threads of the outer ring 84. The diaphragm assembly 92, 94 is threaded onto the outer ring 84 until desired tension is obtained in the diaphragm 92.

At this point in manufacture, the capillary vent apertures can be drilled into the diaphragm 92 so as to provide static pressure equalization for the cartridge. As noted, the diaphragm is very thin, on the order of 4 microns thick, and cannot be unduly handled without deleterious effect. The vent apertures must be formed by means that can provide smooth, even, round holes with little or no force in its formation. Accordingly, in accordance with an embodiment of this invention, formation of the apertures is effected by subjecting the diaphragm to a narrow beam of energy of sufficient intensity to pierce the diaphragm. In a particular embodiment, this energy is obtained by providing means for emitting electromagnetic radiation and coherently stimulating the omission, i.e., by utilizing a laser or maser beam. This aspect is illustrated in FIG. 7 wherein a laser 98 is shown in schematic form and arranged so that its beam 100 is reflected from a half-silvered mirror 102 onto the diaphragm 92 of the cartridge illustrated in FIG. 6D. An appropriately arranged viewing lens 104 and scope 106 are provided for accurately impinging the laser beam onto the diaphragm 92; methods of such alignment and impingement are well known to the laser art.

Referring to FIG. 8, there is illustrated the impingement of a laser beam 100, or the like, onto the thin metallic diaphragm 92 of a cartridge constructed in accordance with the invention herein. Since the spacing 108 between the backplate 82 and the diaphragm 92 is quite close, the high energy beam 100 is directed around the outer periphery of the stretched diaphragm 92, over the insulation 86, so as to preclude welding of the diaphragm to the backplate. As previously indicated, after each aperture is effected, the low frequency response can be measured and additional apertures effected until a desired response is obtained.

Referring to FIG. 9, there is illustrated an alternative method of impinging a beam of high-intensity energy onto the surface of the diaphragm. In this case, a source 110 of electrons is utilized to form a high-intensity electron beam 112 which is focused by an electron beam lens 114 onto the surface of the diaphragm 92, in the manner illustrated in FIG. 8, to effect the formation of apertures therethrough.

Referring to FIG. 10, another embodiment of this invention is illustrated wherein a microphone cartridge 116 is constructed along lines as previously indicated with regard to the cartridge 10 of FIG. 1. Accordingly, there is provided a housing 118 enclosing a backplate 120 supported by means of electrical insulation 122 and an insulator disk 124 so as to be disposed in close proximity to a diaphragm 126 thereover. Apertures are formed in the diaphragm 126 in the manner illustrated in FIGS. 7 or 9. However, the diaphragm ring 128 is provided with an external thread for mating with the internal thread of a second diaphragm ring 130. The second diaphragm ring 130 carries a second thin metallic diaphragm 132 which is similar in construction to the diaphragm 126, but somewhat wider. Following the formation of this double tiered diaphragm structure, the second, outer diaphragm 132 is subjected to beams of energy of high intensity such as illustrated

in FIGS. 7 or 9 to effect the formation of apertures therein. By such means, the outer diaphragm 132 can be tailored to provide desired dynamic pressure filtering for the primary diaphragm 126.

Although the foregoing description has related the formation of apertures subsequent to tensioning of the diaphragm on the cartridge, the apertures could be effected prior to assembly. However, by assembling the cartridge prior to effecting the formation of the diaphragm apertures, the apertures can be more accurately formed and can be correlated with desired transducer properties. Furthermore, although not explicitly stated above, the apertures are most advantageously effected subsequent to temperature cycling and aging of the microphone, i.e., as a last step in its production.

What is claimed is:

1. A method for making an acoustic pressure transducer incorporating a thin metallic diaphragm, comprising: mounting said diaphragm under static tension in close adjacent proximity to the entire front surface of a backplate electrically insulated therefrom so as to form a variable capacitor with said entire front backplate surface which is variable in capacity in response to acoustic pressure variations; and effecting a plurality of capillary vent apertures in the form of round holes through periphery portions of said diaphragm spaced laterally from said backplate to thereby reduce differentials in static air pressure on opposite sides of said diaphragm.
2. The method of claim 1 wherein said aperture is effected subsequent to mounting said diaphragm.
3. The method of claim 1 wherein said diaphragm is mounted so as to form a closed chamber except for said aperture.
4. The method of claim 1 wherein said apertures is effected by subjecting said diaphragm to a narrow beam of energy of sufficient intensity to pierce said diaphragm.
5. The method of claim 4 wherein said beam of energy is ob-

tained by providing means for emitting electromagnetic radiation and coherently stimulating said emission.

6. The method of claim 4 wherein said beam of energy is an electron beam.

7. The method of claim 2 including the steps of:

determining the low frequency response of said transducer; comparing said response to a desired low frequency response; and

effecting the formation of at least one additional vent aperture through said diaphragm to thereby more closely approach said desired response.

8. An acoustic pressure transducer, comprising:

a thin metallic diaphragm;

a backplate; and

means spacing said diaphragm under static tension in close adjacent proximity to the entire front surface of said backplate so as to form a capacitor with said entire front backplate surface which is variable in capacity in response to dynamic pressure variations;

said diaphragm defining a plurality of capillary vent apertures in the form of round holes through periphery portions of said diaphragm spaced laterally from said backplate whereby differentials in static air pressure on opposite sides of said diaphragm are reduced.

9. The transducer of claim 8 including a housing and means electrically insulating said housing from said backplate, said diaphragm housing and insulating means forming a closed chamber except for said capillary vent aperture.

10. The transducer of claim 8 including a second thin metallic diaphragm mounted spaced from the aforesaid diaphragm, said second diaphragm defining at least one capillary vent aperture in the form of a round hole whereby differentials in static air pressure on opposite sides of said diaphragm are reduced to thereby constitute a dynamic pressure filter for said transducer.

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