United States Patent [19]

Barrow

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[45] **Nov. 5, 1974**

[54] **ELECTROACOUSTIC TRANSDUCER OF THE VIBRATILE DIAPHRAGM TYPE WITH CONTROLLED UNIFORMITY OF PERFORMANCE CHARACTERISTICS AND METHOD FOR CONTROLLING UNIFORMITY**

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[52] **U.S. Cl.** **310/8.2,** 310/8.1, 310/8.5, 310/8.8

[51] **Int. Cl.** **H04r 17/00**

[58] **Field of Search** ... 340/10, 14, 17, 8 MM, 8 FT; 310/8–8.3, 8.5, 8.6, 8.7, 9.1, 9.4; 181/.5

[56] **References Cited**

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1,589,962	6/1926	Hecht et al.	340/14 UX
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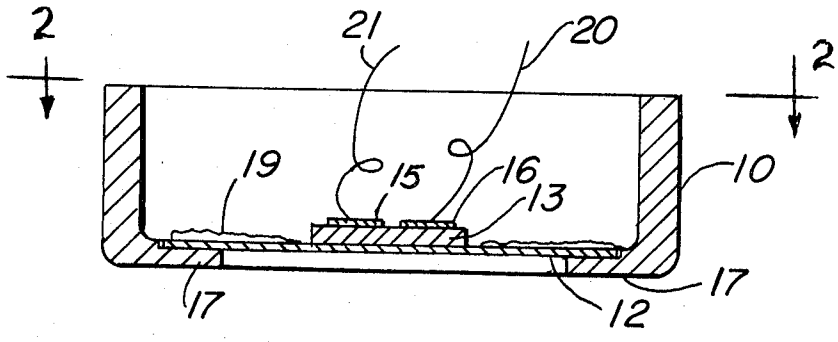
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Primary Examiner—Mark O. Budd

[57] **ABSTRACT**

An operator applies a viscous paste over the surface of a clamped diaphragm in a transducer operating in a flexural resonant mode. The operator literally "paints on" the desired resonant frequency and impedance characteristic of the transducer. These characteristics are continuously monitored, on a suitable meter, while the operator is applying the paste.

8 Claims, 3 Drawing Figures



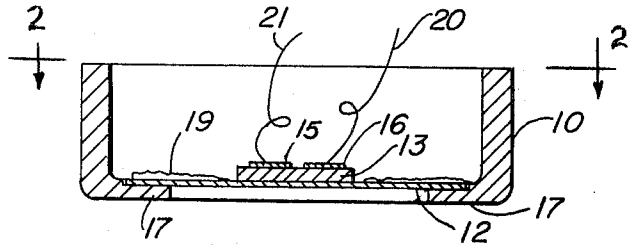


FIG. 1

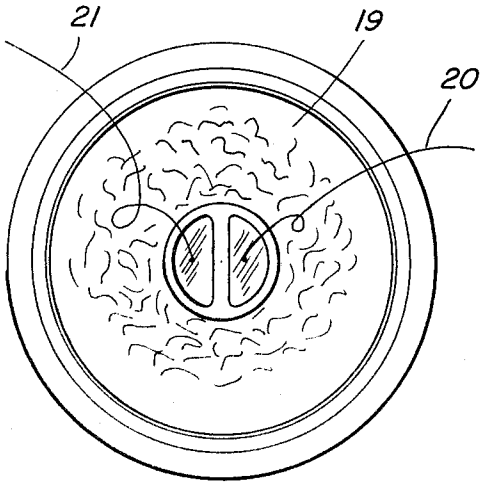


FIG. 2

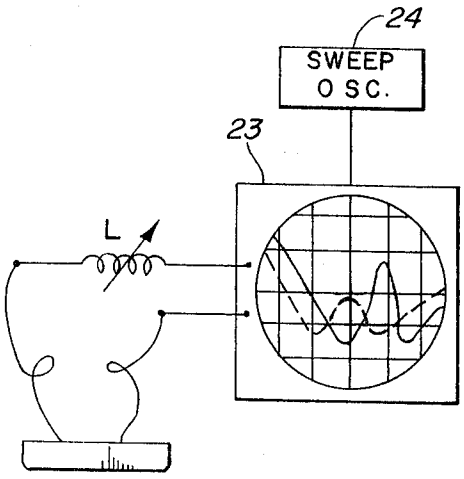


FIG. 3

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ELECTROACOUSTIC TRANSDUCER OF THE VIBRATILE DIAPHRAGM TYPE WITH CONTROLLED UNIFORMITY OF PERFORMANCE CHARACTERISTICS AND METHOD FOR CONTROLLING UNIFORMITY

This invention relates to electroacoustic transducers and more particularly to transducers of the vibratile diaphragm type. Reference is made to a co-pending application Ser. No. 10,748, filed Feb. 12, 1970, by Frank Massa, entitled "ELECTROACOUSTIC TRANSDUCER," and assigned to the same assignee as this invention. The co-pending application shows a similar transducer.

This invention applies to transducers which employ a clamped vibratile diaphragm driven in a flexural resonant mode of vibration. This type of transducer may be operated at either its fundamental resonance or in an overtone mode. When manufacturing large quantities of this type of transducer, it is difficult to control the tolerances of the elements which form the vibrating system. Usually, excessive costs are required to achieve a high degree of uniformity in the transducer frequency response and impedance characteristics.

Accordingly, an object of this invention is to provide transducers of the flexural diaphragm type which achieve a high degree of uniformity in performance characteristics, at very low cost. In this connection, an object is to provide transducers which can be manufactured in large quantities and at low cost, and with acceptable tolerances.

Another object of this invention is to compensate for normally occurring variations in diaphragm dimensional tolerances and variations in assembly tolerances.

A still further object of this invention is to provide low-cost transducers for mass production fabrication, which achieve very accurately controlled uniformity in performance characteristics.

Another object of this invention is to provide a method for adjusting the resonant frequency and impedance of a transducer of the vibratile diaphragm type.

In keeping with one aspect of this invention, these and other objects are accomplished by providing a vibratile disc driven by a piezoelectric transducer. The disc vibrates at its desired mode of vibration. The frequency of this mode is then adjusted to the desired value by brushing a quantity of viscous paste onto the surface of the disc. By further distributing the material over the surface, the impedance of the transducer is brought to a desired value.

These and other objects, features, and advantages of the invention will become more apparent from a study of the following description of an illustrative embodiment of the invention when taken in conjunction with the following accompanying drawings, in which:

FIG. 1 is a cross-sectional view of the vibratile diaphragm portion and housing structure of a transducer assembly incorporating one illustrative embodiment of this invention;

FIG. 2 is a plan view of the structure shown in FIG. 1 and taken along the line 2—2 thereof; and

FIG. 3 is a schematic diagram illustrating the method of making a final adjustment of the resonant frequency and impedance characteristic of the transducer during mass production thereof.

The inventive transducer comprises a ring clamp **10**, diaphragm **12**, and piezoelectric disc transducer **13**. The diaphragm **12** acts as a clamped vibratile disc. The piezoelectric disc **13** acts in its simple flexural mode, driven by a pair of electrodes **15, 16.**

More particularly, the reference character **10** identifies a rigid, somewhat cup-shaped, housing structure having an upstanding annular wall with an inwardly turned ledge **17** at the bottom thereof. Rigidly attached to the ledge **17** is the circular diaphragm **12** which may be bonded thereto at its periphery, by epoxy or any other suitable means. A polarized piezoelectric ceramic disc **13** is bonded to the inside center of the diaphragm **12,** by any suitable rigid cement, such as epoxy. The disc **12** is here shown as being less than one-half the diaphragm area.

This invention may be applied to virtually any type of diaphragm assembly, such as the assemblies illustrated in the above-mentioned co-pending application, for example. However, the invention is equally applicable to frequency control of a diaphragm, whether the diaphragm is or is not clamped at its periphery. The ceramic disc **13** supports the split electrodes **15** and **16** which have electrical conductors **20** and **21** connected thereto. The polarization of the disc and the advantages of the split electrode construction are explained in U.S. Pat. No. 2,967,957.

The diaphragm and ceramic disc dimensions are selected to suit the desired band of frequency operations. More particularly, during manufacture the thickness tolerances of the diaphragm material are deliberately set on the high side. Therefore, any production variations cause the resonant frequency of the transducers to fall out entirely on the high side of the desired limit.

According to the invention, the high frequency elements are brought down to the desired resonance frequency by adding a film of vibrational lossy or rubbery material **19** to the surface of the vibratile diaphragm disc after assembly of the transducers. A suitable material for this application is silicone rubber, which vulcanizes at room temperature. One example of such a material is a product currently sold by Dow Corning, under the trademark "SILASTIC." This silicone rubber material may be painted on with a brush and distributed over the surface of the diaphragm, as required to achieve the desired value of resonance frequency and impedance. The reduction in resonant frequency is determined by the amount of the material which is applied to the diaphragm. The distribution of the material introduces a magnitude of mechanical resistance which, in turn, adjusts the magnitude of the electrical impedance of the transducer.

Other forms of lossy material include discrete layers of material, such as a film with a pressure sensitive adhesive. Also, the material may be added by other means, such as a low melting point solder-like material.

FIG. 3 illustrates a method for monitoring the final adjustment of resonance frequency and impedance. This adjustment requires only a few seconds on the part of a trained operator. More particularly, to adjust an individual transducer to a precise manufacturing tolerance, the transducer is connected in a series circuit including a variable inductance L and the input terminals of an impedance measuring instrument **23.** The instrument **23** displays the impedance of the transducer on

the vertical scale of an oscilloscope tube, as the frequency range is swept along the horizontal scale under the control of a signal generated by the sweep oscillator **24.** A graphical representation which is typical of the pattern obtained on the oscilloscope is illustrated by the solid line.

The procedure for adjusting the transducer characteristics is as follows:

1. Adjust the inductance L to obtain a unity power factor, which is achieved when the height of the peak on the solid curve becomes minimum.
2. Apply damping material **19** to the surface of diaphragm **12.** Brush on the material to move the peak down in frequency to the desired value, as illustrated by the dotted curve.
3. Distribute the material **19** over the diaphragm surface to vary the mechanical damping until the height of the peak on the dotted curve is decreased to a specified magnitude. In FIG. **3,** the desired impedance is illustrated as the center horizontal line on the oscilloscope screen. The center vertical line represents the desired resonance frequency value for the transducer.

Thus, I have shown an exemplary transducer design employing a vibratile diaphragm element which can be very simply and economically manufactured in large quantities. There is an accurately controlled response and impedance characteristic.

The type of vibratile structure described above was selected to illustrate the basic principles of my invention. The invention itself is the method of achieving high precision, low-cost control over uniformity of characteristics during manufacturing. Those skilled in the art will readily perceive how to apply the teachings of my invention to other types of vibratile diaphragm structures. For example, these diaphragms may be circular, square, clamped edge, or free edge. Also, the invention applies to other types of flexural vibrating transducer structures, such as reed surfaces. Therefore, it should be understood that various modifications may be made without departing from the true spirit and scope of the invention, and the claims are to be construed to cover all equivalent structures.

I claim:

1. An electroacoustic transducer comprising a rigid housing structure including a diaphragm attached at its periphery to said housing structure, a piezoelectric disc rigidly bonded to one side of said diaphragm for vibrating said diaphragm, and means comprising a flexible film of vibrational lossy material coating at least a portion of a surface of said diaphragm for lowering the resonance of said transducer to a predetermined frequency, said lossy material having a characteristic wherein it adheres to said diaphragm when applied in a liquid state, and thereafter solidifies to a solid state, said material further having a characteristic in said solid state wherein the internal molecular working of said material absorbs energy without distorting the vibrational pattern of said diaphragm.

2. The invention in claim **1** characterized in that said flexible film of material is a silicone rubber compound.

3. The transducer of claim **1** wherein said lossy material is positioned on the surface of said diaphragm at locations which adjust the magnitude of motional impedance to predetermined levels.

4. The invention of claim **3** wherein said piezoelectric disc is bonded to the center of said diaphragm, said piezoelectric disc having a diameter substantially smaller than the diameter of said diaphragm, and said lossy material covers at least a circular portion of said disc at a circumference on the surface of said diaphragm which is between the periphery of said peizoelectric disc and the periphery of said diaphragm.

5. The invention of claim **3** wherein said piezoelectric disc is substantially smaller than said diaphragm, said disc and diaphragm being concentrically oriented in said bonded relationship, and two semi-circular electrodes bonded to the side of said piezoelectric disc which is not bonded to said diaphragm.

6. The invention of claim **5** and conductor means connected to each of said semi-circular electrodes for completing an electrical circuit across a gap between said electrodes.

7. The invention of claim **3** wherein said lossy material is a rubbery material.

8. The invention of claim **3** wherein said flexible film is distributed over an outer circumferential surface of said diaphragm with substantially no flexible material in the central portion of said diaphragm.

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