July 6, 1948. A. L. W. WILLIAMS ET AL 2,444,620

DAMPING MEANS FOR MECHANICAL VIBRATORY DEVICES

Filed June 23, 1944 2 Sheets-Sheet 1

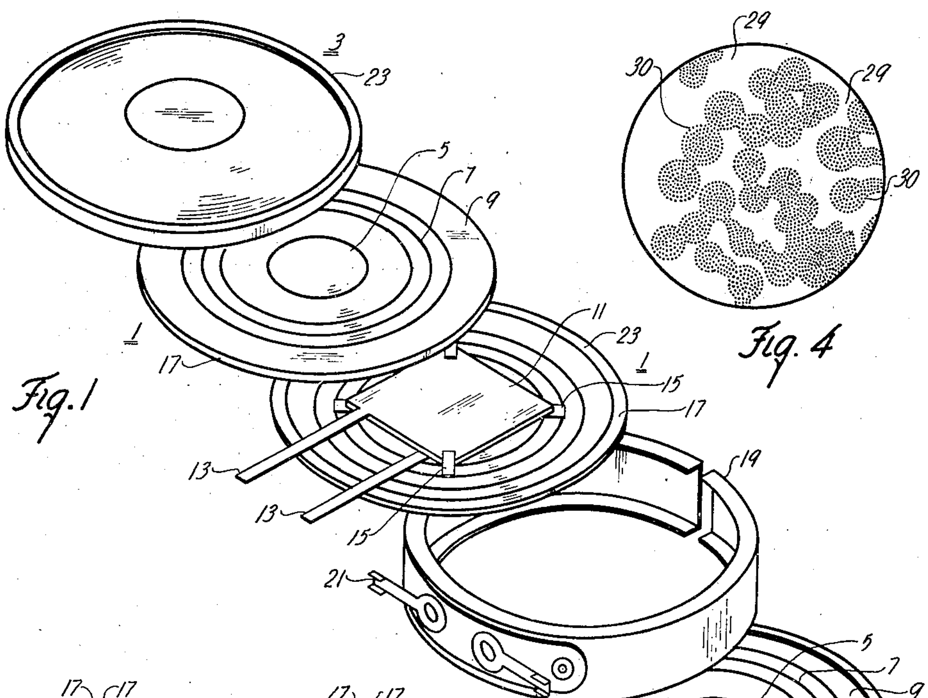

Fig. 1

Fig. 4

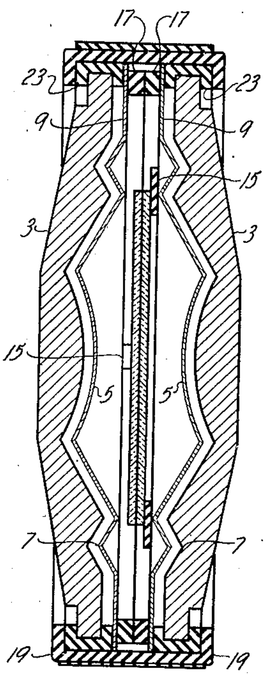

Fig. 2

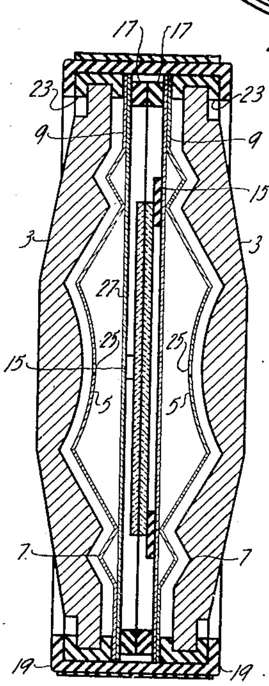

Fig. 3

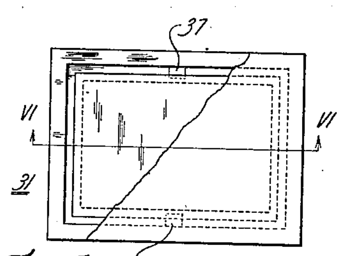

Fig 5

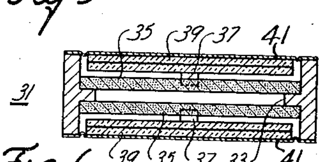

Fig. 6

INVENTOR.
ALFRED L. W. WILLIAMS
DEAN R CHRISTIAN

BY E.R. Goldsborough
ATTORNEY.

July 6, 1948. A. L. W. WILLIAMS ET AL **2,444,620**

DAMPING MEANS FOR MECHANICAL VIBRATORY DEVICES

Filed June 23, 1944 2 Sheets-Sheet 2

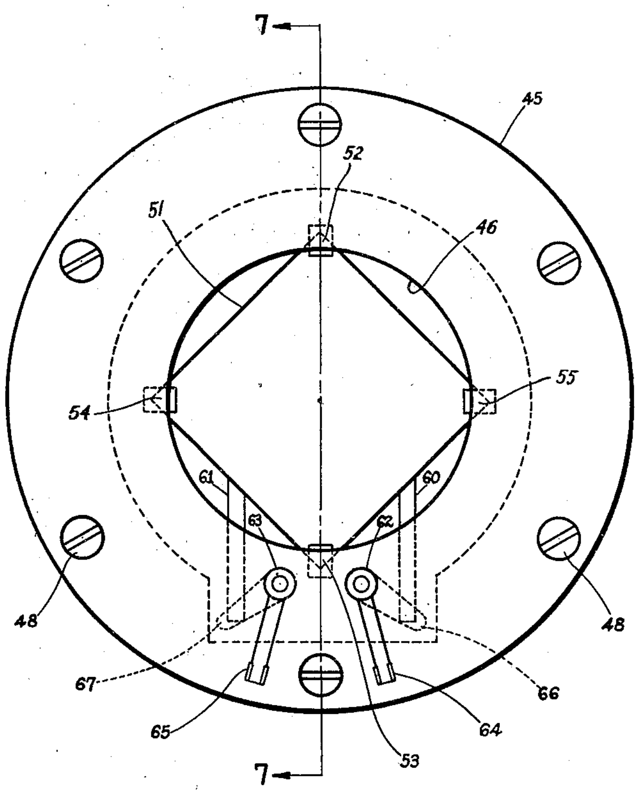

FIG. 8

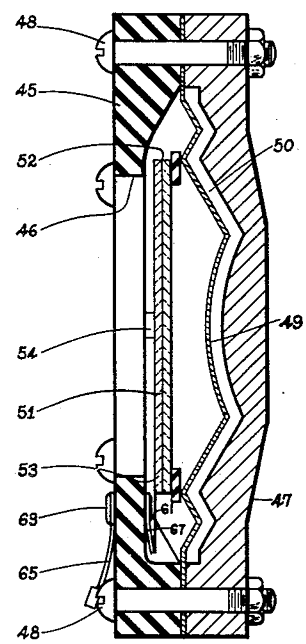

FIG. 7

INVENTOR.
ALFRED L.W. WILLIAMS
DEAN R. CHRISTIAN

BY Elias J. Hyde
ATTORNEY

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DAMPING MEANS FOR MECHANICAL VIBRATORY DEVICES

Alfred L. W. Williams, Cleveland Heights, and Dean R. Christian, Medina, Ohio, assignors to The Brush Development Company, Cleveland, Ohio, a corporation of Ohio

Application June 23, 1944, Serial No. 541,694

9 Claims. (Cl. 179—110)

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This application is a continuation-in-part of our application Serial Number 429,896, filed February 7, 1942, and now abandoned.

This invention relates to mechanical vibratory devices in general and, more particularly, to damping means for such devices and for sound transducers of the type wherein undesirable response peaks or resonances occur, such as microphones comprising piezoelectric crystal sections.

In order best to employ a piezoelectric crystal section, or an opposing pair of connected crystal sections such as are shown and described in Re. 20,213 and Re. 20,680, in a microphone it is expedient to transfer sound-pressures thereto by way of an associated diaphragm having appreciable stiffness. Such a diaphragm, however, together with the crystal which it drives, has a definite resonance frequency that usually lies within or just outside the range of sound-frequencies for which the microphone is designed, giving rise to a highly objectionable peak in the response curve of the microphone.

Attempts to eradicate the resonance peak, or peaks, have been made by disposing damping material adjacent to a vibratile diaphragm, as shown in the patent to Stewart et al., 1,488,565, by disposing the diaphragm in a housing open at the rear to the atmosphere through controllable orifices, and by numerous other means familiar to those skilled in the art.

Other vibratory devices, such as loud speakers, phonograph pickups, telephone receivers and the like, sometimes require damping; to them, also, this invention is broadly applicable.

Having the foregoing requirements in mind, it is an object of our invention to provide improved means for damping a vibratory mechanical system.

An object of this invention is to provide a damping material capable of exerting high acoustic damping on a microphone diaphragm, or other diaphragm, adjacent to which it is disposed.

Another object of this invention is to provide a damping material that shall be so rigid as to be capable of being utilized in the construction of a microphone housing.

Another object of this invention is to provide a damping material, of the type described, that

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shall be unaffected by climatic conditions and not subject to deterioration in ordinary use.

Another object of this invention is to provide what might be termed a microphone cartridge wherein the casing thereof serves as damping means for the diaphragm or diaphragms therein that transfer sound pressures to a piezoelectric crystal element of the multi-plate flexing type.

Another object of this invention is to provide a unitary microphone housing and damping element that shall be substantially unaffected by rough usage.

Another object of this invention is to provide a microphone wherein the usual housing or case is eliminated and one that may be manufactured at a relatively low cost as compared with heretofore known microphones.

Another object of this invention is to provide a microphone that shall be sealed against moisture and the operativeness of which shall not be detrimentally affected by changes in the static pressure of the medium in which it is utilized.

Another object of this invention is to provide means whereby the extremely small motion of a vibrating piezoelectric crystal element may effectively be damped.

A still further object of this invention is to provide a damping material having such characteristics that it may itself, be utilized in the construction of a microphone-housing or case.

In a preferred embodiment of this invention, the foregoing objects and other objects ancillary thereto are preferably attained by providing a novel damping material, constituted by a plurality of sintered-together minute discrete particles, which material is sound-permeable but is sufficiently rigid to withstand reasonably rough treatment. The particles, preferably, are metallic spherules, and the material, after sintering, is self-supporting and is sufficiently rigid to be utilized as an element of the housing for a diaphragm-crystal assembly. Furthermore, the diaphragm is disposed very close to the inner surface of the housing-element, which surface has a contour complementary to the contour of the diaphragm and the peripheries of the element and the diaphragm are sealed to provide a closed air chamber.

The novel features that are considered characteristic of this invention are set forth with particularity in the appended claims. The invention itself, however, both as to its organization and its method of operation, together with additional objects and advantages thereof, will best be understood from the following description when read in connection with the accompanying drawings in which:

Figure 1 is an exploded view in perspective of a piezoelectric microphone cartridge of the sound-pressure type, exemplifying a preferred embodiment of the invention;

Figure 2 is an enlarged cross-sectional view of the assembled microphone cartridge;

Figure 3 is an enlarged sectional view of the microphone cartridge shown in the preceding figures, slightly modified for use at varying altitudes;

Figure 4 is a reproduction of a photomicrograph taken of a polished and etched portion of a damping plate section, the magnification being about 70 diameters;

Figure 5 is a plan view of an alternative embodiment of the invention, partly broken away to better show the interior construction thereof,

Figure 6 is a view, in vertical section, taken along a line corresponding to the line VI—VI in Figure 5.

Figure 7 is a cross-sectional view of a modified form of microphone embodying our invention taken along line 7—7 of Figure 8, and

Figure 8 is a plan view looking toward the back of the microphone illustrated in Figure 7.

In all figures of the drawing, identical elements are similarly designated.

Referring now to the drawing, a preferred embodiment of this invention is exemplified by a microphone comprising a pair of similar quasi-conical metallic diaphragms indicated generally by numerals **1**, **1**, disposed base to base and enclosed in a housing constituted by two plates **3**, **3** of the improved sound-permeable damping material. It will be noted from Figures 1, 2 and 3 of the drawing that each diaphragm has a central portion **5** in the form, generally, of a truncated cone, the truncated portion of which is slightly dished, and that the base of the conical portion of each diaphragm is surrounded by an annular ridge **7** that is triangular in radial cross-section, the ridge, or corrugation, being integral with a flat annular mounting rim **9**.

Disposed between the diaphragms is a multiplate crystal element **11** of the "twister" type, one pair of the diagonally opposite corners thereof being affixed to the base of the conical portion of one diaphragm and the other pair of diagonally opposite corners thereof being affixed to the base of the conical portion of the opposite diaphragm. Because of the configuration of the diaphragms, the central conical portion of each moves as a piston when the assembled device is subjected to sound pressures. In use, the diaphragms move toward and from each other in unison, subjecting the crystal element to bending stresses around diagonals thereof, thus inducing potentials, at the electrodes, corresponding to the combined excursions of the diaphragms. The crystal element is provided with a pair of output leads **13**, **13**, connected to the electrodes (not shown).

In Figure 1 the crystal element is shown merely as being affixed to one of the diaphragms, but it is to be clearly understood that in the process of assembly the pair of opposite corners referred to are cemented or otherwise affixed to the opposite diaphragm. Preferably, a small ear or tab **15** of "Celluloid," cellulose acetate, or "Vinylite" is cemented or otherwise affixed to each corner of the crystal assembly, the pairs of tabs serving, respectively, as coupling elements between the diaphragms and the crystal element to which they are cemented, and the assembly comprising diaphragm means connected to a crystal element may be termed a microphone "cartridge" and sold as such.

As will be noted from Figure 2, the diaphragms are spaced apart by two annular rings **17**, **17** of a phenolic condensate product such as "Bakelite" or the like, between which extend, in the finished device, the conductive leads **13**, **13** from the crystal element. The cover or damping plates **3**, **3**, are disposed, respectively, on each side of the dual-diaphragm-crystal assembly and are clamped thereto by an encircling, internally channeled split ring **19** of "Bakelite," hard rubber, metal, or the like, to form the diaphragm housing. The clamping ring **19** carries two eyeleted terminals **21**, **21** through which the leads **13**, **13** extend, respectively, in the assembled device, and to which the said leads are externally soldered.

The inner surface of each cover plate is spaced approximately 0.02 inch apart from the diaphragm by annular spacer rings **23**, **23**, which rings, in Figure 2 of the drawings, are shown as encircling and sealing the peripheries of the damping plates **3**, **3**. The rings, preferably, are made from a material such as "Vinylite," that prevents vibrations from being transferred between the diaphragms and the damping plates and also damps vibration of the plates **3**, **3** themselves.

The clamping ring **19**, when sprung into place and fastened by any suitable means (not shown) exerts radial and axial stresses on the diaphragm-damping-element assembly, so compressing the spacing rings **23**, **23** carried by the peripheries of the damping elements as to effectively seal the rim of the assembly against ingress and egress of air. Accordingly, during utilization of the microphone, any air flow between the interior and the exterior of the housing, such as would be caused by extraordinary excursions of the diaphragms at resonance, must be through the minute pores of the damping material, and such flow is effectively impeded.

The space between the diaphragms being sealed, as described, the trapped air changes in volume as the atmospheric pressure changes. A minute opening **25**, shown in Figure 3, may be provided through each diaphragm but in such case the crystal must be protected against moisture. For that purpose, a thin, flexible diaphragm **27**, of rubber or the like, is interposed between each of the sound receiving diaphragms **1**, **1** and the crystal, as shown also in Figure 3. When such sealing diaphragms are utilized, the crystal element is protected against moisture. Furthermore, changes in the volume of the trapped air are permitted by the flexible diaphragms, thus keeping stresses from being imposed on the connections between the tabs **15** and the main diaphragms **1**, **1**.

The material preferably utilized according to this invention for the combined microphone housing and damping element is metallic in character. In the proper selection of this material resides one of the most important phases of this invention. Specifically, the material in question is made by molding and thereafter sintering a mass of spheroidal metallic particles in an inert or reducing atmosphere, at a temperature below the melting point thereof, to form a homogeneous body or plate penetrated by microscopically small tortuous air passages that are irregular in extent and diameter. The metallic particles are preferably of copper, globular or spheroidal in shape and, in the specific material utilized for microphone-damping plate of the type described, they have an average diameter of the order of .004 inch. That is to say, the particles are such as will pass through a 100 mesh screen and be retained on a 150 mesh screen. The actual sizes of the particles are evident from an inspection of Figure 4, which shows a small section of a plate of the material, perpendicular to a face thereof, enlarged 70 diameters.

Although copper particles alone may be molded under pressure and sintered to form a plate of damping material, it is found more advantageous to utilize a mixture of 90% copper particles and 10% tin particles. The tin particles, which preferably are so small as to be practically dust, wet the copper spheroids in the sintering process, and provide better adhesion between them. Alloying of the copper particles may also take place, the final material then comprising a variety of bronze.

After sintering, approximately 40% by volume of the material is constituted by air passages and air pockets, designated by numeral **29** in Figure 4. The porosity of the material is dependent upon the average size of the spheroidal particles, the molding pressure and the sintering temperature; the finer the particles, the smaller the interstices and, consequently, the higher the acoustic impedance. The molding pressure must not be so excessive as to materially deform the particles and to close the passages between them. From an inspection of Figure 4 it will be evident that the particles **30** show little deformation which is a desirable condition.

It is purely fortuitous that the particle-size appears variable in Figure 4. Such appearance is because the particles lay at random positions with respect to the plane of the section examined microscopically.

The sintering temperature should be below the melting point of the alloy that might be formed by the particles and the metal. If tin and copper are employed, sintering may be accomplished at temperatures ranging from 1100° to 1300° Fahrenheit, depending upon the desired damping characteristics.

Particles of other metals, such as nickel, for example, or of alloys, may be sintered together, or they may be mixed with still other alloying metals having lower melting points than the particles themselves and sintered. Instead of simply mixing the copper or other particles with particles of tin, lead or analogous material, fair results may be obtained by coating the individual copper spherules with tin before molding and sintering. The method of coating copper particles with tin is well known in the art, and is described in U. S. Patent to George E. Best, 2,255,204.

In order to reduce resonance of the damping plates **3**, **3** themselves, a small percentage of lead particles or particles of an analogous non-elastic substance may be mixed with the copper particles before molding and sintering. Furthermore, in lieu of a single plate, two or more plates may be cemented together, at a number of spaced apart points, by "Viscoloid" or other non-drying adhesive. Preferably, if several plates are cemented together, their thicknesses should be different in order to further reduce resonance of the composite plate. Such modifications, it is believed, are sufficiently clear as to require no illustration.

The damping plates **3**, **3** are permeable to sound, and, although they are closely coupled to the diaphragms, in use they offer low impedance to normal movements of the diaphragms compared to the stiffness of the mechanical vibratory system including the diaphragms themselves. At resonance, however, when the impedance of the mechanical system drops to a low value and the excursions of the diaphragms thereof tend to become excessive, the rapid flow of displaced air through the plates is resisted by the minuteness of the passageways therethrough, thus imposing heavy damping on the diaphragms.

In greater detail, the action of the damping plates may be described as follows: the sintered metal plates permit passage of air through the plates but the passages are so small that the flow of air meets substantial resistance. The plates thus act as acoustic resistance elements. Due to the small size of the air passages, the acoustic inertance of the passages is negligible compared with the resistance. The damping plates are disposed in sealing engagement with the peripheries of the diaphragms so that there are formed between the plates and the diaphragms small cavities which act as acoustic coupling elements between the diaphragms and the acoustic resistances. Thus the acoustic resistances are coupled to the mechanical vibratory system consisting of the crystal element and the diaphragms. Due to the proportions of the elements this resistance introduced into the mechanical system is small compared with the mechanical impedance of the vibratory system at frequencies well below and well above resonance. The acoustic resistance therefore has little effect on the behavior of the microphone throughout the lower part of its useful frequency range. Near resonance, however, the impedance of the vibratory system becomes very low so that the acoustic resistance has relatively great effect. Thus in the neighborhood of resonance the mechanical system cannot vibrate freely at large amplitude under the stimulus of a small driving force as it would without the presence of the damping plates because if it were to do so it would force relatively large quantities of air back and forth through the acoustic resistance elements dissipating therein a substantial amount of energy. In order that the acoustic resistance may exert sufficient control on the mechanical system it is necessary that the acoustic resistance element be closely coupled to the diaphragm. If the volume of this chamber is increased too much, the acoustic resistance is "short circuited" by the acoustic compliance of the cavities so that it cannot exert proper resistance control on the vibratory system. We have found that in the device shown in Figures 1, 2, and 3 a spacing of about .020 inch may be employed.

The net result of the utilization of damping plates constructed according to our invention is the realization of a microphone the response of which is substantially flat over a desired range and the sensitivity of which is substantially as great as that of a similar device which is devoid of means for damping the diaphragms.

As disclosed in the Stewart et al. Patent No. 1,488,565, damping means have heretofore been proposed for microphones. Insofar as it is known, however, no one previous to this invention has proposed the use of damping material having such physical characteristics as to permit its utilization for the housing of a microphone, nor has it previously been proposed to utilize sintered metallic particles for such purpose.

From the foregoing description, it is not to be inferred that this invention is limited to a microphone of the double diaphragm type. On the contrary, it is equally as well applicable to microphones, such as shown in the Stewart patent, having only a single diaphragm and to all other acoustical apparatus wherein damping through controlled air flow is helpful.

This invention is also directly applicable to microphones of the general type disclosed in the United States Patent to Sawyer 2,105,010 and the United States Patent to Williams 2,126,437. That is to say, instead of disposing the damping plate adjacent to a diaphragm that actuates a piezoelectric crystal element or is actuated thereby, it has been found advantageous in some instances to mount the said damping plate in close proximity to the crystal element itself.

A microphone, referring now to Figs. 5 and 6 of the drawing, embodying this invention may comprise a mounting frame designated in its entirety by the numeral **31**, which frame may be square as shown, or which may have any other contour desirable. The frame is provided with an interior ledge **33** to the upper and lower surfaces of which are cemented or otherwise affixed plates **35**, **35** of the sintered damping material hereinabove described. Each plate carries two thin spacers **37**, **37** of suitable material such as "Bakelite," or the like, these spacers being disposed diametrically opposite each other at the midpoints of opposite sides of the plate. The spacers may be cemented or otherwise affixed to the surface of each damping plate or the plates, as indicated by dotted lines in Figure 6, may each be provided with a small channel for the purpose of receiving the spacers and of holding them in fixed position. A piezoelectric element **39** of the multiplate bender type is centrally supported upon each pair of the spacers **37**, the outer surface of each element being cemented to a flexible covering sheet **41** which extends beyond the crystal element and is cemented to the adjacent edge of the surrounding frame.

The spacing between the inner surface of each piezoelectric element and the associated damping plate is extremely small to avoid "short circuiting" of the high acoustic resistance required to damp the crystal elements which have a high mechanical impedance.

At frequencies well below resonance the impedance of the crystal elements is so high that the resistance provided by the damping plates has negligible effect on the vibrations of the elements. Near resonance, however, the mechanical impedance of crystal elements becomes very low so that the resistance provided by the damping plates has a controlling influence, preventing strong resonance peaks. The volume of the central space is such that but little "stiffness" reaction is introduced thereby, the resistive damping action of the plates being predominant. In microphones of the usual type, the spacing between the damping plates may be of the order of ⅛ of an inch.

In order to still further increase the useful range of the microphone thus far described, in some instances it is desirable to utilize crystal elements having differing natural frequencies.

In the event that crystal elements having different natural frequencies are utilized, they will resonate at different times during normal utilization of the microphone provided, of course, that both resonant frequencies are not simultaneously present in the sound received. When one alone tends to vibrate at its resonance frequency, it will tend to displace more air than the other element which is vibrating with normal amplitude. The extra air displaced will tend to move through the interstices in the adjacent partition, and the friction developed will damp the vibration to a greater or less degree depending upon the composition of the damping material, the spacing between the crystal element and the plate, and the "stiffness" of the central air chamber. As above pointed out, the microphone is so designed that the damping plates do not materially affect the motion of the crystal element during the reception of sound at other frequencies.

It will be noted that in the improved microphone construction shown in Figures 5 and 6 the damping plates are so disposed that they damp the resonant vibrations of the crystal elements without intercepting the sound waves which actuate the elements.

In a modified microphone the sintered metal damping plates may be positioned to form portions of the protective housing, as has been previously described, and in this modified construction the soundwaves pass through the sintered metal damping material.

Figures 7 and 8 illustrate a pressure gradient microphone embodying our invention. It is comprised of a "Bakelite" or other electrically nonconductive base or frame member **45** which has an opening **46** in the back face thereof through which sound waves are admitted and a rigid front member **47** comprised of porous sintered metal connected to the back member by means such as connecting bolts **48**. The peripheral portion of a diaphragm **49** is sealingly clamped between the edges of the front and back members **47**, **45** and the remainder of the diaphragm is positioned close to but spaced apart from the porous sintered metal member **47** to establish an enclosure **50** which is substantially air tight except for minute air channels which extend through the porous sintered metal. A multiplate flexing piezoelectric crystal element **51** of the twister type is mounted with two diagonally opposite corners **52**, **53** in driving relationship with the diaphragm **49** and with its other two diagonally opposite corners **54**, **55** braced against the frame member **45**. Mounting pads and adhesive may be used between the crystal corners **52**, **53** and the diaphragm **49** and between the crystal corners **54**, **55** and the frame member **45**. Leads **60**, **61** from the crystal element **51** are connected as by soldering to terminals **66**, **67** which are mounted within the microphone by means of tubular rivets **62**, **63** extending through the frame member **45** and to which are connected outside terminals **64**, **65** for connecting the microphone into an electrical circuit.

As has been explained in connection with the previous figures, the volume of the enclosure **50** and the number and size of the minute air channels through the porous sintered metal **49** are so related to each other and to the vibratory system that the resonance frequency vibrations of the vibratory system comprised of the diaphragm **49** and the crystal element **51** are effectively damped.

This microphone acts as a pressure gradient microphone due to the fact that both sides of the diaphragm **49** are directly accessible to sound waves, on one side through the porous sintered metal plate 47, and on the other side through the opening 46.

Other advantages of this invention should readily be apparent to those skilled in the art to which it pertains. Among them may be mentioned the fact that this improved damping material is vastly more effective than any material such as felt, blotting paper, wool or the like or material such as is disclosed in the aforementioned Stewart patent. It is not known definitely why this improved damping material is so effective but it is thought that its remarkable damping action results from the microscopic sizes and irregular directions of the air passages therethrough.

In addition, through the utilization of an improved damping material, it is possible to dispense entirely with microphone housings of usual types and, accordingly, this invention permits of material reduction in manufacturing costs.

The material does not deteriorate in use as does felt or the like, and it is substantially unaffected by climatic conditions.

Additional modifications and embodiments of this invention will be obvious to those skilled in the art to which it pertains. This invention, therefore, is not to be restricted except insofar as is necessitated by the prior art and by the spirit of the appended claims.

We claim as our invention:

1. In combination, a vibratory mechanical system comprising a diaphragm having a non-planar surface configuration, the system having a resonance frequency, a substantially rigid member spaced apart from but closely adjacent to the face of said diaphragm and including at least a portion formed of sintered-together minute discrete particles having a plurality of minute air channels therethrough, means sealing said rigid member to the peripheral edge of said diaphragm to form an enclosure substantially air-tight except for said minute air channels, the volume of said enclosure and the number and size of the minute air channels through said portion formed of sintered particles being such that sufficient acoustic resistance load is imposed on the said vibratory system to effect substantial damping of its resonace frequency vibrations, the surface of said rigid member facing said diaphragm having a configuration closely approximating the surface configuration of said diaphragm whereby said resistance load is imposed substantially uniformly on said diaphragm.

2. The combination as set forth in claim 1, further characterized in this: that said rigid member comprises at least part of a protective housing for said diaphragm.

3. In combination, a resonant vibratory system including a diaphragm having a peripheral edge portion, a substantially rigid support for said diaphragm comprising a body of sintered-together minute discrete particles sealingly engaging the peripheral edge portion of said diaphragm with the remainder of the said diaphragm disposed closely adjacent to but spaced apart from the support to form an enclosure substantially air-tight except for the minute air passages through the said sintered body, the number and size of the said minute air passages and the volume of the said enclosure being so related to each other and to the vibratory system that sufficient acoustic resistance is introduced into the vibratory system to effect substantial damping of its resonance frequency vibrations.

4. The combination as set forth in claim 3, further characterized in this: that said rigid support comprises at least part of a protective housing for said diaphragm.

5. In combination, a vibratory mechanical system comprising a pair of interconnected acoustical diaphragms disposed in face-to-face spaced apart relationship and having a resonance frequency, a pair of substantially rigid bodies each associated with one of said diaphragms and each spaced apart from but closely adjacent to a face of the diaphragm with which it is associated and each of said rigid bodies including at least a portion formed of sintered-together minute discrete particles having a plurality of minute air channels therethrough, means sealing each of said rigid bodies to the peripheral edge of its respective diaphragm to form two enclosures each of which is substantially air tight except for the said minute air channels in the sintered bodies, the volume of said enclosures and the number and size of the minute air channels through said sintered bodies being such that sufficient acoustic resistance load is imposed on the said acoustical system to effect substantial damping of its resonance frequency vibrations.

6. The combination as set forth in claim 5, further characterized in this: that each of said rigid bodies comprises at least part of a protective housing for said diaphragm.

7. In combination, a microphone cartridge including a non-planar vibratory element having a resonance frequency and a protective housing therefor comprising porous sintered-together minute discrete particles closely acoustically coupled to said vibratory element substantially throughout the entire vibratory area of said vibratory element to act also as an acoustic resistance element for said vibratory element to substantially damp the resonance frequency vibrations thereof.

8. In a transducer, a resonant vibratory system including a diaphragm having a front and a back face and having a resonance frequency, a substantially rigid member spaced apart from but closely adjacent to one of the said faces of said diaphragm and including at least a portion formed of porous sintered-together minute discrete particles having a plurality of minute air channels therethrough and sealingly engaging the peripheral edge of said diaphragm to form an enclosure substantially air tight except for said minute air channels, the volume of said enclosure and the number and size of said minute air channels through said sintered portion being such that sufficient acoustic resistance load is imposed on the said diaphragm to effect substantial damping of its resonance frequency vibrations, and frame means connected to said substantially rigid member and only partially covering the other face of said diaphragm whereby sound vibrations may reach the said diaphragm from both front and back directions.

9. In an acoustic electro-mechanical transducer device, a vibratory system including a diaphragm having a peripheral edge portion, said vibratory system having a resonance frequency within the frequency range of said transducer device, a plate-like body of sintered-together minute discrete particles having a plurality of narrow tortuous paths therethrough by which air can pass from one side of the plate to the other, sealing means connecting the peripheral edge portion of said diaphragm to the edge of said plate-like body with the face of said diaphragm closely adjacent to but spaced from a major face of said plate-like body to form a cavity between

the diaphragm and the plate-like body which is sealed from the outside except for the said plurality of narrow paths through said plate-like body, the number and size of the said narrow air paths and the volume of the said cavity being so related to each other and to the vibratory system that acoustic resistance is introduced into the vibratory system to effect substantial damping of its resonance frequency vibrations.

ALFRED L. W. WILLIAMS.
DEAN R. CHRISTIAN.

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