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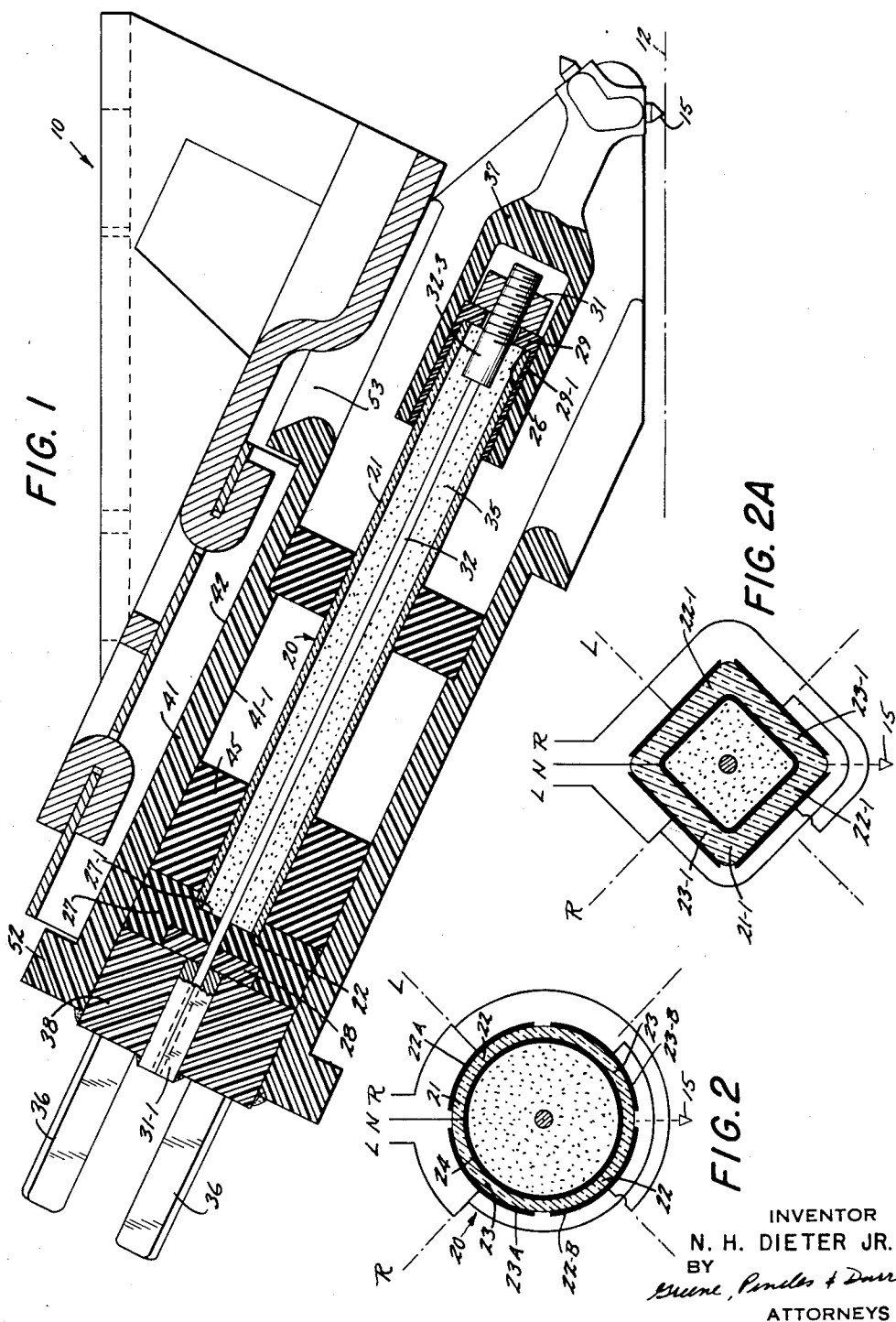
N. H. DIETER, JR

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REINFORCED HOLLOW PIEZOELECTRIC CERAMIC TRANSDUCER STRUCTURES

Filed July 1, 1958

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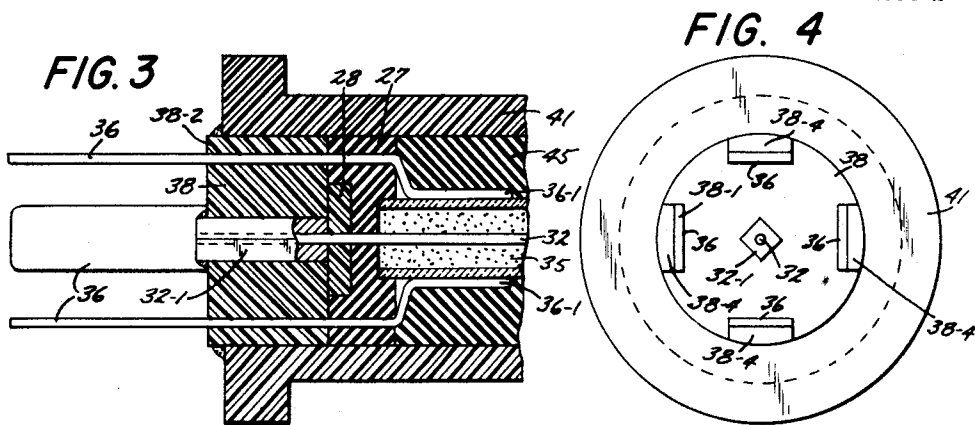
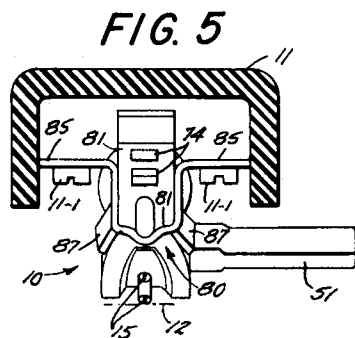
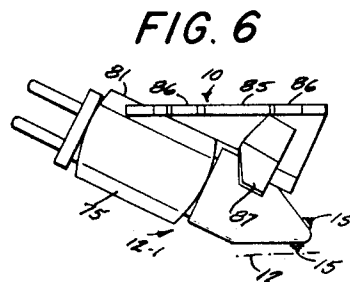
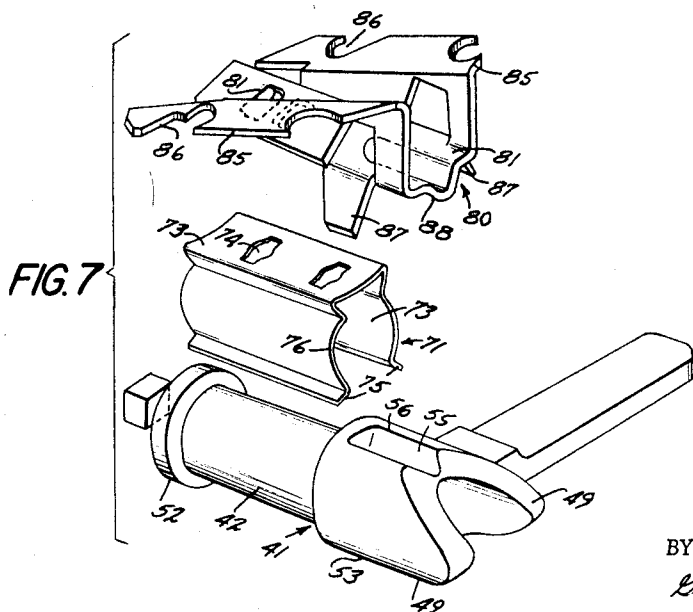
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2 Sheets-Sheet 2



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REINFORCED HOLLOW PIEZOELECTRIC CERAMIC TRANSDUCER STRUCTURES

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8 Claims. (Cl. 310-9.4)

This invention relates to piezoelectric ceramic transducers which transduce mechanical signals into electric signals and vice versa, and particularly to hollow tubular transducers of this type. There are available piezoelectric transducers consisting of a thin tubular ceramic body which has been rendered piezoelectric by application of electric polarizing fields and designed for operation with a mechanical vibratory transducing mode in transducing devices such as phonograph pickups, microphones, and other applications. To be effective, such ceramic transducer has to be made with a very thin ceramic body about .010" or less in thickness. Such thin, hollow ceramic transducers exhibit only minute tension strength and are very fragile and break excessively when assembled with cooperating elements into a practical transducer device, and when handled in use with less than extreme care.

Among the objects of the invention is a thin, tubular ceramic transducer structure in which the danger of breakage of its fragile body is materially reduced; and a thin, tubular ceramic transducer device the ceramic body of which is maintained under compression for reducing the danger of breakage when subjected to tension strains.

The foregoing and other objects of the invention will be best understood from the following description of an exemplification of the invention, reference being had to the accompanying drawings, wherein:

Fig. 1 is a vertical cross-sectional view of one form of a phonograph pickup cartridge operating with a ceramic transducer exemplifying the invention;

Fig. 2 is a cross-sectional view of the transducer structure of Fig. 1 and its operative circuit connections;

Fig. 2-A is a view similar to Fig. 2 showing another type of tubular ceramic transducer of the invention;

Fig. 3 is a cross-sectional view similar to Fig. 1, of the rear portion of the same transducer along a cross-sectional plane displaced 45° from the cross-sectional plane of Fig. 1;

Fig. 4 is a rear end view of the transducer structure of Figs. 1-3, as seen from the rear end thereof shown in Fig. 3;

Fig. 5 is a front end view of the phonograph cartridge of Fig. 1, as it is held mounted in the tone arm of a phonograph;

Fig. 6 is a side elevational view of the pickup cartridge of Fig. 5; and

Fig. 7 is an exploded view showing the relationship of the transducer housing and the mounting bracket by means of which it is held on the tone arm.

Although it is obviously of broader scope, the invention will be described in connection with a tubular, hollow piezoelectric ceramic transducer designed for operation in applications such as stereophonic pickups having two distinct sets of ceramic body segments, each distinctly polarized for operation with a predetermined mechanical mode distinct from the mechanical mode of the other set of ceramic body segments thereof. Al-

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though such ceramic transducers are of value in various other applications, it will be described herein in connection with a practical stereophonic phonograph cartridge designed for playing back the two stereophonic undulation sequences along different segmental regions of the adopted standard 45-45 stereophonic record groove system. In such standard 45-45 stereophonic record system, a single stylus of the playback cartridge moves in engagement with two segmental record undulation sequences formed along the two side walls of a record groove extending under 45° to a horizontal record surface.

Referring to Figs. 1, 2 and 3-7, there is shown a pickup cartridge generally designated 10, held in its operative position on the downwardly facing side of the front end of a conventional tone arm 11 of a conventional disc phonograph, with one of the two styli 15 of the pickup engaging a record disc indicated by dash-line 12 (Figs. 5 and 6). The record disc 12 is arranged to rotate in a conventional way in clockwise direction indicated by arrow 12-1, around a generally vertical axis, and the individual record traces or grooves of the disc are of substantially circular shape. The tone arm 11 has a rear end (not shown) which is mounted in a conventional way so as to permit rotation of the tone arm around a vertical axis and also for upward tilting of the tone arm. The particular pickup shown is intended to reproduce signals from records formed by a laterally cut groove which imparts to the stylus 15 a lateral undulatory motion. However, the pickup shown may be readily designed for operation with a vertically cut record groove, or with a record groove cut in any other direction.

The pickup shown is designed for operation with the novel mechano-electric transducer of the invention generally designated 20 and shown in detail in Figs. 1-4. It comprises a tubular, thin piezoelectric ceramic body 21 extending along a straight central axis and to which the desired piezoelectric properties have been imparted by the application of unidirectional electric polarizing fields. Any of the known ceramic materials which may be rendered piezoelectric by the application of an electric polarizing field, may be used for the ceramic transducer body 21. Among such materials are the various titanates, such as barium, lead, zirconium titanates, and also other ceramic substances which may be rendered piezoelectric, including niobates such as lead metaniobate. In practice, good results are obtained with ceramic transducers 21 formed with barium titanate, and still better results are obtained with lead and zirconium titanates, and lead, zirconium and barium titanates.

The ceramic transducer body 21 is designed to operate with two sets of distinct ceramic transducer sections each with distinct piezoelectric orientation along a distinct piezoelectric axis so that one ceramic transducer section operates with a vibratory mode distinct from the vibratory mode of the other ceramic transducer section. To this end, as shown in Fig. 2, the ceramic body 21 is provided with a set of two diametrically opposite body segments 22 and with another laterally displaced set of two diametrically opposite body segments 23. The different body segments of ceramic tube 21 are provided with outer and inner surface electrodes. Thus the two body segments 22 are provided with outer surface electrodes 22-A, 22-B, and the two body segments 23 are provided with outer surface electrodes 23-A, 23-B. The two sets of opposite transducer segments 22, 23 are also provided on their inwardly facing surfaces with inward surface electrodes for thereby applying differential polarization to the different ceramic body segments 22, 23 by a unidirectional electric polarizing field so that one set of the transducer segments

22 operates with one distinct vibratory transducer mode, and the other set of transducer segments 23 operates with another distinct vibratory transducer mode. Although each of the transducer segments 22, 23 may be provided with a distinct inward electrode, they are shown provided with a common neutral inner electrode 24. The surface electrodes 22-A, 22-B, 23-A, 23-B are formed in a conventional way, as by fusing silver glass frit which is rich in silver, to the outer electrode surfaces of the ceramic body 21.

In its particular application as a transducer for a stereophonic pickup, the set of two diametrically opposite transducer segments 22 is piezoelectrically polarized so that they vibrate as a bender with a vibratory transducer mode in a plane extending under 45° to the record surface 12, as indicated in Fig. 2 by a dash-line axis L, for cooperation with one undulation sequence of the record groove. The other set of diametrically opposite transducer segments 23 is piezoelectrically polarized so that they vibrate with a similar vibratory bender transducer mode in a 90° displaced plane, likewise extending under 45° to the record surface 12, and indicated in Fig. 2 by dash-line axis R, for cooperation with the other undulation sequence of the record groove. In their practical application, to supply signals for two distinct speakers of a stereophonic playback system, the two outer electrodes 22-A and 22-B of one set of transducer segments 22 are connected in parallel between output lead 25-L and neutral lead 25-N from the inner common electrode 24 of the ceramic transducer, which leads 25-L, 25-N serve to supply one speaker of the stereophonic playback system. The two outer electrodes 23-A, 23-B of the other set of transducer segments 23 are similarly connected in parallel between output lead 25-R and the neutral lead 25-N leading from the inner common electrode 24 of the ceramic transducer 23 to the other speaker of the stereophonic system.

The ceramic transducer tube 21 may have any suitable cross-sectional shape. When designed to have two sets of diametrically opposite segments polarized to operate with distinct vibratory bender modes in two 90° displaced planes, as explained above, good results are obtained by making the ceramic transducer tube 21 with a cylindrical shape, as indicated in Fig. 2, or with a rectangular or generally square shape, as indicated in Fig. 2-A, having outer and inner surface electrodes arranged and connected in the same way as in the tube 21 of Fig. 2. The ceramic transducer tube 21-1 of Fig. 2-A, which has a square cross-section, has its two sets of diametrically opposite segments 22-1, 23-1 polarized in the same way as the corresponding segments of tube 21 of Fig. 2, respectively, so that the two sets of opposite segments 22-1, 23-1 vibrate with two distinct bender modes in two 90° displaced planes.

The forward end of the ceramic transducer tube 21 is arranged to be driven by either one of the two styli 15. The opposite rear end of the ceramic transducer tube 21 is arranged to be held restrained against motion by a portion of the relatively rigid housing or mounting body 41 of the cartridge 10 within which it is held restrained against motion by an elastomer bias body 45 surrounding the rear part of the transducer.

The ceramic transducer tube 21 has to have a very small wall thickness of only about .010" or less, and is very fragile and easily broken. Such thin ceramic body is also easily fractured when subjected to tension strains. In accordance with the invention, the ceramic transducer tube 21 is provided with restraining means which engage its opposite edge borders 26 and apply thereto axial compression forces which maintain the ceramic tube walls under compression and thereby minimize their tension strains when in operation or when external forces are applied thereto. In addition, danger of breakage of the fragile ceramic body is greatly reduced by filling all available free interior space thereof with a filler body of yieldable material which, while permitting the desired vibra-

tory transducer flexing of the transducer sections of the ceramic body 21, provides effective mechanical backing for the fragile, thin walls thereof.

In Figs. 1 and 3, is shown one manner of applying axial compression forces which maintain the side walls of the ceramic tube 21 under axial compression and thereby minimize tension strains both in its operation as a transducer and also when subjected to external forces, as when handling the pickup in applying it to a record disc or removing it therefrom, or moving it from one record disc portion to another. A clamping body comprising an inner clamping member 27 and overlying member 28 is placed over the rear end edge border 26 of the ceramic transducer tube 21 so that it overlies and applies compression forces to the tube border when pressed against it. Against the opposite forward border 26 of ceramic tube 21 is also placed a clamping body comprising an inner clamping member 29 and an overlying member 31 so that it overlies and applies compression forces against the underlying ceramic tube border 26 when held pressed against it.

The two sets of composite clamping bodies 27, 28 and 29, 31 overlying the opposite tube borders 26, are held clamped against them for applying compression forces to the walls of the ceramic body 21 in the direction of its axis, by a tensioning member 32, the opposite ends of which are secured in suitable clamping engagement to the opposite clamping bodies 27, 28 and 29, 31, respectively. In the form shown, clamping body 27 overlying the rear tube border 26 is formed of a rubber-like material such as neoprene, being of greater width than the ceramic tube 21, and being of substantially the same width as the housing compartment space 41-1 within which the rear part of transducer tube 21 is held. The side of the rubber-like clamping body 27 which faces the ceramic tube 21 has formed therein a body recess 27-1 for holding therein with a tight fit a short rear end portion of ceramic tube 21 engaged thereby. Against the outer side of the rubber-like clamping body 27, is held clamped the overlying rigid clamping member 28 of metal, for instance, which overlies the tube border 26 for applying through the rubber body 27 axial compression forces to border 26 and there-through to the walls of the ceramic tube 21. The opposite inner clamping body 29 overlying the opposite tube border 26 is made of relatively stiff but somewhat yieldable material such as relatively hard synthetic resin, for instance nylon or linear polyethylene. This clamping body 29 has a thin rim portion 29-1 overlying and engaging with a relatively tight fit the adjoining sides of the tube border region of the ceramic tube 21, so that together with its main body overlying the tube border 26, axial compression forces will be properly applied thereby to the walls of the ceramic tube 21 when it is pressed against the tube border 26 by the overlying rigid clamping member 31.

The tensioning member 32 is flexible and extends along the neutral zone of the transducer 21 where it has only a negligible effect on the compliance and operating characteristics of the two sets of ceramic-tube transducer segments 22 and 23. Tensioning member 32 may be formed, for instance, of a thin, strong metal wire, for instance of stainless steel, Phosphor bronze, beryllium copper, or the like, or other wire or thread-like material which has great tensile strength. In the application for a transducer tubing 1" long and having a diameter of .050", a tensioning member 32 consisting of a circular wire .010" to .020" of steel, is satisfactory for applying the desired compression forces to the ceramic tube 21, without substantially affecting its transducer operating characteristics.

The tensioning wire 32 extends through interfitted holes of rubber clamping member 27 and the overlying rigid clamping member 28, and has secured to its outer

end a fixed clamping head 32—1 which overlies and holds under clamping compression the rigid clamping member 28. The clamping head 32—1 may consist of a shank of metal such as steel, having a central hole within which the engaged end of tensioning wire 32 is affixed, as by cementing or soldering it therein, or by electric spot-welding of side wall portions of the shank 32—1 to the portion of the tensioning wire 32 passing therebetween.

To the opposite forward end of the tensioning wire 32 is secured as by cementing, soldering or electric spot-welding, a metal sleeve 31—2, the exterior outer region of which is provided with a fine thread shaped for engagement with a corresponding inner threaded surface of the outer nut-like metallic clamping member 31. The tensioning member 32 to which the threaded clamping member 31—2 has been previously secured may have its other thin end properly inserted and passed through the aligned central holes of the assembled clamping members 27, 28, whereupon the head 32—1 is placed over the rear end of the tensioning wire 32 and secured thereto, as by forming an electrical spot-weld connection between them.

In accordance with the invention, all free interior space of ceramic transducer tube 21 is filled with a flowable but incompressible filler material which provides a backing body 35 for the fragile ceramic walls thereof, without materially affecting its transducer compliance. In accordance with the invention, the filler body 35 is formed of a liquid which may be placed in the interior of the hollow ceramic transducer tube 21 after applying the closure clamping bodies to one end thereof, and before the other end thereof is completely closed.

After mounting the tensioning member 32 in its operative clamping relation to the assembled damping members 27, 28, they are placed in the clamping position over the rear tube border 26 so that the opposite threaded end portion 32—3 of the tension member passes through the opposite end of ceramic tube 21. Thereupon the inner clamping member 29 is placed in its operative clamping position over opposite tube border 26 and the threaded clamping nut 31 is threaded over the threaded tension wire end portion 32—3 until by turning the clamping nut collar 31, compression forces of proper magnitude are applied in axial direction to the walls of ceramic tube 21. The magnitude of the applied compression forces may be so adjusted as to minimize or reduce to zero tension, strains that might be developed in normal transducing operations of ceramic transducer tubes in their application as phonograph cartridge transducers. Thus, before applying the clamping nut 31 to the threaded end portion 32—3 of tensioning member 31, or while the clamping nut 31 is held withdrawn inwardly within tube 21, its interior space is filled with the damping liquid through the wide open front end of tube 21. Thereupon the tensioning member is moved to its final inward position shown, and any additional free spaces within the interior of the ceramic tube 21 are filled fully with the liquid through the central opening in clamping member 29, and thereafter the clamping nut 31 is secured to the threaded tensioning member end 31—2 and tightened, for sealing the interior space of the tube 21 and applying the desired compression forces to its ceramic walls. One of the closure clamping bodies, for instance, the two rear end clamping members 27, 28, may be provided with two holes passing axially from the exterior space into the interior space of tube 21 for injecting into the interior space of ceramic tubing 21 such liquid, while air from the interior is discharged through the other opening of the closure body.

In accordance with the invention, the filler liquid body placed in the ceramic transducer tube is a vibration damping liquid which exhibits substantial internal fric-

tion when subjected to vibrations. Desirable damping liquids are silicone damping oils. By using as a liquid filler, silicone oil of the type disclosed and claimed in Smith-Johannsen application Serial No. 605,308, filed

August 21, 1956, there is assured that the interior space of the ceramic transducer tube 21 will remain filled with such liquid without danger of the liquid leaking to the exterior space through any filler opening provided in its clamping end closure bodies. Such filling of damping fluid 35 within the interior of the transducer tube 21 is also of great value in assuring that any vibratory resonant modes of any elements thereof, for instance, of the tensioning wire 32, will be damped, thereby securing desirable transducer operating characteristics. To the forward end of the ceramic transducer 21 is connected the groove-engaging stylus 15 by a stylus mounting member 37. The stylus mounting member 37 is relatively rigid and may be formed of synthetic resin material, with a compartment surrounding the forward closed end of ceramic tube 21 with its closure elements 29, 31, 32—3, and to which the forward end of the ceramic tube is secured as by a layer of cement placed between them. The stylus 15 is mounted at the forward end of the stylus mounting member 37 so as to movably engage the stereophonic record groove of a record disc 12 rotating on a horizontal plane. Stylus mounting member 37 holds the stylus in such position relatively to the two sets of transducer segments 22, 23 which are designed to be vibrated in two mutually perpendicular planes L, R (Fig. 2), that the motion imparted to the stylus by the two distinct undulation sequences of opposite sides of a 45—45 stereophonic record groove, will be resolved into two distinct motion components corresponding to the two distinct undulation sequences of the record groove, respectively, for causing one transducer segment set of the two sets of transducer segments 22, 23 to deliver an electric output corresponding to one record undulation sequence, and the other transducer segment set to deliver an electric output corresponding to the other record undulation sequence. This relationship of the stylus 15 with the two sets of ceramic tube segments 22, 23 is indicated in Figs. 2, 2—A, by the position of stylus 15, which extends axially in a vertical plane which is displaced 45° relatively to the planes indicated by dash-lines R and L of the vibratory modes of the two sets of tube segments 22, 23 which are correspondingly flexed by the respective stylus motion components. The motion of the stylus is thus resolved into two motion components imparted to the two sets of transducer segments 22, 23, respectively, in a manner corresponding to the motion components imparted by the single stylus to two distinct transducer sets of a stereophonic pickup, as described in my co-pending application Serial No. 740,760, filed June 9, 1958.

The rear region of the ceramic transducer tube 21 is restrained against flexing and held in its operative position within the ceramic compartment 41—1 of cartridge housing and mounting structure 41 by an elastomer bias body 45. The elastomer body 45 holds the rear end region of the ceramic transducer tube 21 under proper bias so that the component transducer motions imparted by the stylus to its two sets of 90° displaced transducer segments 22, 23, will generate across their respective electrodes, corresponding electric output delivered to the two speakers, in the manner indicated by the circuit diagrams of Figs. 2 and 2—A, respectively. The rear end region of the ceramic transducer tube 21 is also provided with electric terminals by means of which its electrode surfaces are connected to the electric output circuits, of the type indicated in Figs. 2 and 2—A. To this end, the rubber closure clamping member 27 holds mounted and embedded in slits thereof, intermediate portions of four metallic terminal strips 36, each

having on its inward side a contact end portion 36—1 which is held pressed into contact engagement with the underlying surface electrodes of the corresponding four transducer segments 22 and 23 of the ceramic tube 21. A closure wall member 38 of relatively hard insulating material, such as polystyrene or nylon, is arranged to fit and close the opening at the rear end of housing 41 to fix therein in properly oriented position the transducer tube 21. As indicated in Fig. 4, the hard closure member 38 has a polarized opening, for instance of rectangular or square shape, arranged to fit over the correspondingly polarized outer aligning surface of tension member head 31—1 which forms a fixed part of the ceramic transducer tube 21.

When securing the tensioning member 32 in fixed clamping engagement to the ceramic tube 21, its polarized or rectangular tensioning head 31—1 is oriented so that its four corners extend in alignment with the center region of the four transducer segments 22, 23 of the ceramic transducer tube 21. This assures that when the polarized or rectangular tensioning head 31—1 is held fixed in oriented position relatively to the transducer housing 41, the four transducer segments 22, 23 will likewise be retained in proper oriented position relatively to the transducer housing 41.

The closure wall 38 is provided with recesses or slits 38—1 for locating and holding therein the terminal strips 36 extending in rearward direction from the rubber-like closure member 27. Closure end wall 38 may be affixed to the ceramic tube transducer assembly, for instance by placing it in aligned position over tensioning member head 32—1 and securing it thereto as by cement, which may also be applied over the adjoining regions thereof along the rearward adjoining end face portions thereof. The so-assembled transducer structure with the elastomer body 45 placed thereon, is then inserted into operative position, as shown, within transducer housing 41. Thereupon, after proper aligned operative orientation relatively to housing 41, the end wall member 38 is suitably secured to the surrounding transducer housing wall 41, as by interfitting pins (not shown) or by cement 38—2 applied to their adjoining outer end surfaces. The terminal slits 38—1 may be open in the direction toward the circular periphery of the closure end wall 38. After placing the closure end wall 38 in its operative position within the transducer housing 41, filler wedges 38—4 of resin or metal may be driven in the open space of terminal slits 38—1 to fix the position of the terminal strips 36 and also to provide good clamping connection between the end wall 38 and the surrounding transducer housing 41. The wedges 38—4 may also be affixed in their position shown, by cement.

The pickup shown in Figs. 1, 2 and 3—7, is designed for playing back stereophonic sequences either from fine microgrooves which require a stylus 15 with a fine stylus tip, or from stereophonic records with a wider record groove such as used in 78 r.p.m. records requiring a stylus with a thicker stylus tip. To this end, the stylus mounting member 37 has mounted therein and carries two differently directed styli 15 so that by rotating the ceramic transducer tube 21 180° around its axis, either of the styli 15 will be brought into operative groove-engaging position. The transducer housing member 41 is provided with an outer rotary seat surface 42 which is rotatably supported on a rotary guide structure 71 of a mounting support by means of which it is held affixed in operative position in the tone arm 11, as seen in Figs. 4—7. The guide structure 71 is formed of a spring sheet metal strip deformed to provide a central mounting section 73 with two arcuate clamping arms 76 elastically biased to hold clamped between them and fix the position of the seating surface of the transducer housing 41 and retain it in the operative position on the tone arm. The guide structure is joined to the tone arm by a complementary bracket 80. The bracket 80 is likewise formed of sheet

metal and has a central section to which the central mounting section 73 of guide structure 71 is secured by two struck-out bracket lugs 82 passing through clamping slots 74 of central guide sheet section 73 and clampingly bent over the inward surface, as seen in Fig. 5. The central bracket sheet section 81 is adjoined by two bent side arms which terminate in outwardly bent lateral clamping arms 85 having cut-out openings 83 for receiving clamping screws 11—1 by means of which bracket 81 is clamped to mounting lug of tone arm 11. The housing 41 and the cooperating guide and clamping structure 71, 80 are otherwise identical with those described in the co-pending application Serial No. 733,680, filed May 7, 1958, my myself and Egon H. Bauer.

The transducer housing unit 41 also has a laterally projecting grip arm 51 by means of which it may be easily turned from one stylus position to the opposite stylus position. The housing is made from synthetic resin material. The bracket sheet 80 has struck therefrom two stop arms 87 which are bent outwardly and shaped to be engaged by housing grip arm 51 when it brings the transducer-housing unit 41 to either one of its opposite stylus positions. The housing 41 is provided with a circular stop rim 52 at the rear end thereof, and with a wider forward housing body part 53 so that they face and remain in sliding engagement with the opposite edge surfaces 76 of the two arcuate guide arms 73 of housing guide structure 71.

The central sheet section 81 of the forward part of sheet bracket 80 has formed thereon a central rounded outwardly bent stop ridge 88 shaped to lockingly engage the side surfaces 56 of either one of two locking recesses 55 formed on the exterior of the wider forward section 53 of transducer housing 41. The opposite side surfaces 56 of each of the two opposite housing locking recesses taper outwardly and sideward, so that—on turning the housing unit 41 to an opposite stylus position—the respective tapered recess surfaces 56 on coming into engagement with the bracket bias ridge 88, will be actuated thereby and by the spring forces of guide and clamping arms 73 to move with a snap action to its new stylus position.

It will be apparent to those skilled in the art that the novel principles of the invention disclosed herein in connection with specific exemplifications thereof, will suggest various other modifications and applications of the same. It is accordingly desired that in construing the breadth of the appended claims they shall not be limited to the specific exemplifications of the invention described above.

I claim:

1. In a piezoelectric transducer device, a thin, hollow ceramic tube body having tube walls extending along a tube axis and two opposite tube ends, said tube body being composed of ceramically joined particles and rendered piezoelectric in a common selected direction, said tube body having permanent piezoelectric properties imparted by temporary application of common electric polarization thereto for causing said tube body to transduce with a predetermined mechanical mode, and restraining means including an end member engaging each tube end and a tensioned restraining member extending through the interior of said tube body and engaging the two end members for maintaining its fragile ceramic wall portions under axial compression and thereby minimizing tension strains thereof while transducing with a vibratory mode transverse to said axis, the cross-sectional area of said restraining member being only a relatively small fraction of the cross-sectional area of said tubular body.

2. In a piezoelectric transducer device, a thin, hollow ceramic tube body having tube walls extending along a tube axis and two opposite tube ends, said tube body being composed of ceramically joined particles and rendered piezoelectric in a common selected direction, said tube body having permanent piezoelectric properties imparted

by temporary application of common electric polarization thereto for causing said tube body to transduce with a predetermined mechanical mode, restraining means including an end member engaging each tube end and a tensioned restraining member extending through the interior of said tube body and engaging the two end members for maintaining its fragile ceramic wall portions under axial compression and thereby minimizing tension strains thereof while transducing with a vibratory mode transverse to said axis, and yieldable filler material substantially filling all available interior space of said hollow ceramic body and provides a backing body which resists fracture of its fragile ceramic wall portions.

3. In a piezoelectric transducer device, a thin, hollow ceramic tube body having tube walls extending along a tube axis and two opposite tube ends, said tube body being composed of ceramically joined particles and rendered piezoelectric in a common selected direction, said tube body having at least one set of diametrically opposite tube segments extending generally parallel to said axis along different segmental regions of said tube body, said tube body having permanent piezoelectric properties imparted by temporary application of common electric polarization thereto for causing said tube segments to transduce with a predetermined mechanical mode, and restraining means including an end member engaging each tube end and a tensioned restraining member extending through the interior of said tube body and engaging the two end members for maintaining its fragile ceramic wall portions under axial compression and thereby minimizing tension strains thereof while transducing with a vibratory mode transverse to said axis, the cross-sectional area of said restraining member being only a relatively small fraction of the cross-sectional area of said tubular body.

4. In a piezoelectric transducer device, a thin, hollow ceramic tube body having tube walls extending along a tube axis and two opposite tube ends, said tube body being composed of ceramically joined particles and rendered piezoelectric in a common selected direction, said tube body having at least two sets of diametrically opposite tube segments extending generally parallel to said axis along different segmental regions of said tube body, each set of opposite body segments having permanent piezoelectric properties imparted by temporary application of common electric polarization thereto for causing each set of transducing segments to transduce with a predetermined mechanical mode distinct from the mechanical mode of the other set of body segments, yieldable filler material substantially filling all available interior space of said hollow ceramic body and provides a backing body which resists fracture of its fragile ceramic wall portions, and restraining means engaging the opposite body borders of said tube body for maintaining its fragile ceramic wall portions under axial compression and thereby minimizing tension strains thereof while transducing with a vibratory mode transverse to said axis, the cross-sectional area of said restraining member being only a relatively small fraction of the cross-sectional area of said tubular body.

5. In a piezoelectric transducer device, a thin, hollow ceramic tube body having tube walls extending along a tube axis and two opposite tube ends, said tube body being composed of ceramically joined particles and rendered piezoelectric in a common selected direction, said tube body having at least one set of diametrically opposite tube segments extending generally parallel to said axis along different segmental regions of said tube body, said set of tube segments having permanent piezoelectric properties imparted by temporary application of common electric polarization thereto for causing said tube segments to transduce with a predetermined mechanical mode, and yieldable filler material substantially filling all available space of said hollow ceramic body and providing a backing body which resists fracture of its fragile

ceramic wall portions, restraining means including an end member engaging each tube end and a tensioned restraining member extending from the interior of said tube body and engaging the tube ends for maintaining the fragile ceramic wall portions of said tube under axial compression and thereby minimizing tension strain thereof while transducing with a vibratory mode transverse to said axis, the cross-sectional area of said restraining member being only a fraction of the cross-sectional area of said tube body.

6. In a piezoelectric transducer device, a thin, hollow ceramic tube body having tube walls extending along a tube axis and two opposite tube ends, said tube body having at least one set of diametrically opposite tube segments extending generally parallel to said axis and having permanent piezoelectric properties imparted thereto by temporary application of electric polarization for causing said tube segments to transduce with a predetermined mechanical mode, and yieldable filler material substantially filling all available space of said hollow ceramic body and providing a backing body which resists fracture of its fragile ceramic wall portions, restraining means including an end member engaging each tube end and tensioned restraining means for maintaining the fragile ceramic wall portions of said tube under axial compression and thereby minimizing tension strain thereof while transducing with a vibratory mode transverse to said axis, said restraining means including two opposite clamping structures overlying said opposite tube ends and a tensioning member extending through the interior of said hollow body and connected to said opposite clamping structures for subjecting said opposite tube ends to compression forces.

7. In a piezoelectric transducer device as claimed in claim 6, at least one of said clamping structures including an elastomer body portion of rubber-like material interposed between said one clamping structure and the tube end along which said clamping structure extends for causing said elastomer body portion to store at least some elastic restoring energy whereby said tube body is maintained under axial compression.

8. In a piezoelectric transducer device, a thin, hollow ceramic tube body having tube walls extending along a tube axis and two opposite tube ends, said tube body being composed of ceramically joined particles and rendered piezoelectric in a common selected direction, said tube body having at least two sets of diametrically opposite tube segments extending generally parallel to said axis along different segmental regions of said tube body, each set of opposite body segments having permanent piezoelectric properties imparted by temporary application of common electric polarization thereto for causing each set of transducing segments to transduce with a predetermined mechanical mode distinct from the mechanical mode of the other set of body segments, and restraining means including an end member engaging each tube end and a tensioned restraining member extending through the interior of said tube body and engaging the two end members for maintaining its fragile ceramic wall portions under axial compression and thereby minimizing tension strains thereof while transducing with a vibratory mode transverse to said axis, the cross-sectional area of said restraining member being only a relatively small fraction of the cross-sectional area of said tubular body.

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