June 23, 1936. E. C. NICHOLIDES 2,045,404

PIEZOELECTRIC VIBRATOR DEVICE

Filed May 24, 1933 2 Sheets-Sheet 1

Fig. 1.

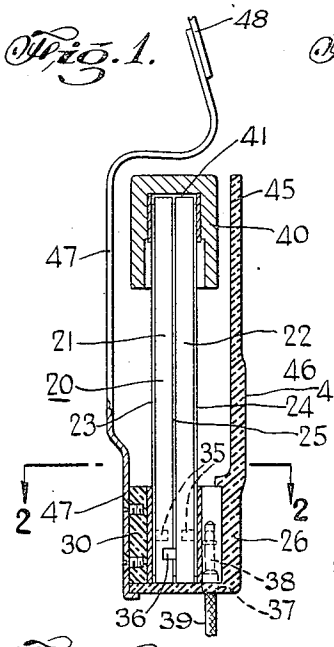


Fig. 3.

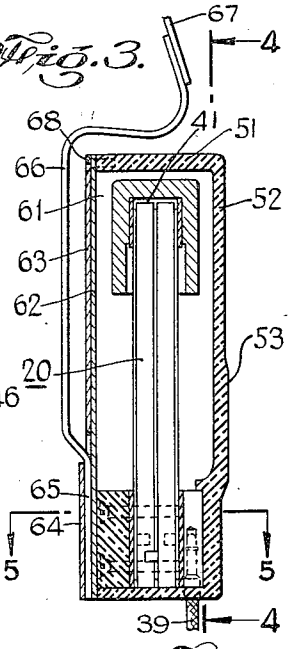


Fig. 4.

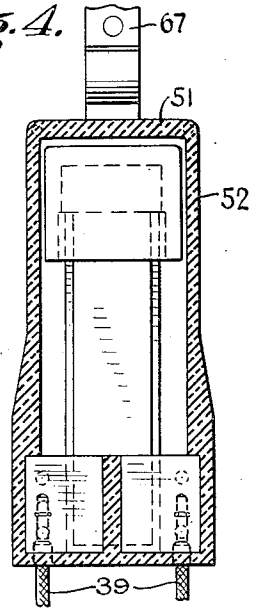


Fig. 2.

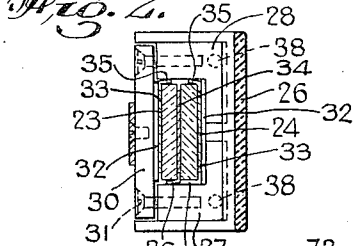


Fig. 5.

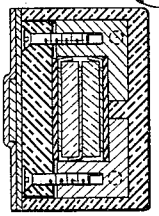
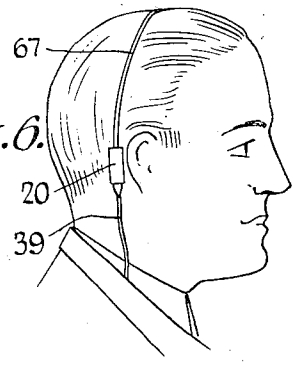


Fig. 6.



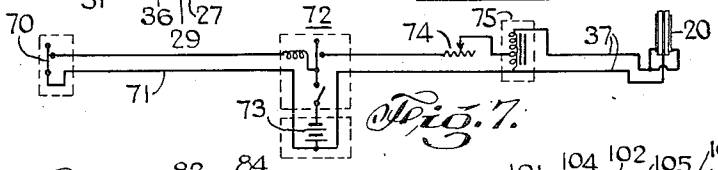


Fig. 7.

Fig. 8.

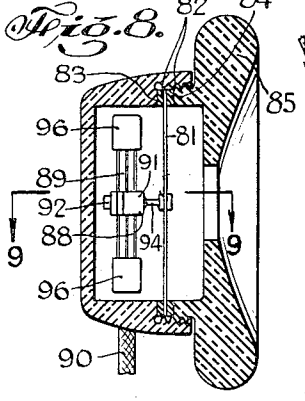
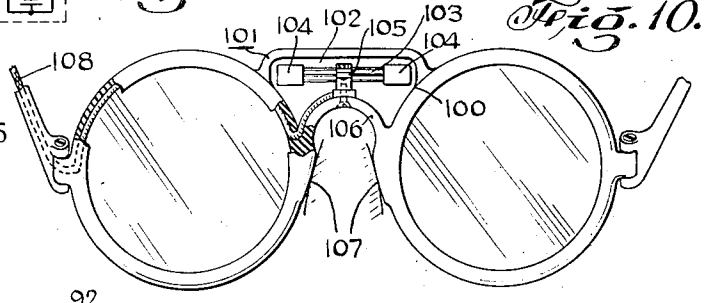


Fig. 10.



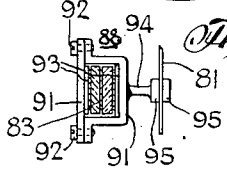


Fig. 9.

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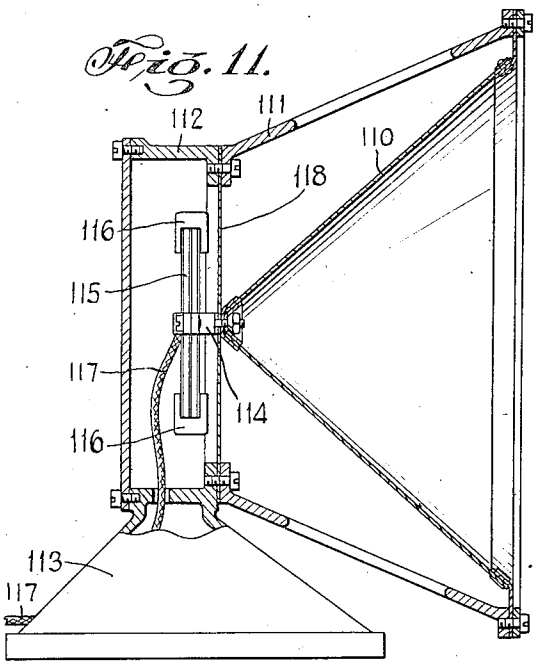
June 23, 1936. E. C. NICHOLIDES 2,045,404

PIEZOELECTRIC VIBRATOR DEVICE

Filed May 24, 1933 2 Sheets-Sheet 2

Fig. 11.



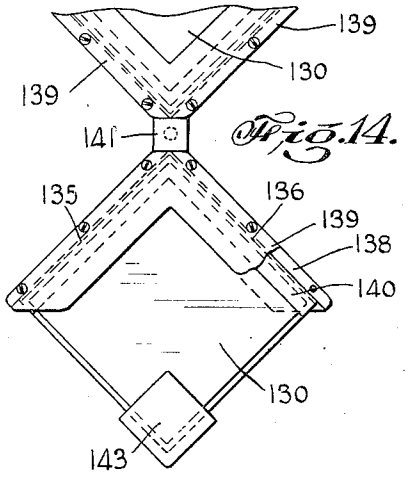


Fig. 14.

Fig. 12.

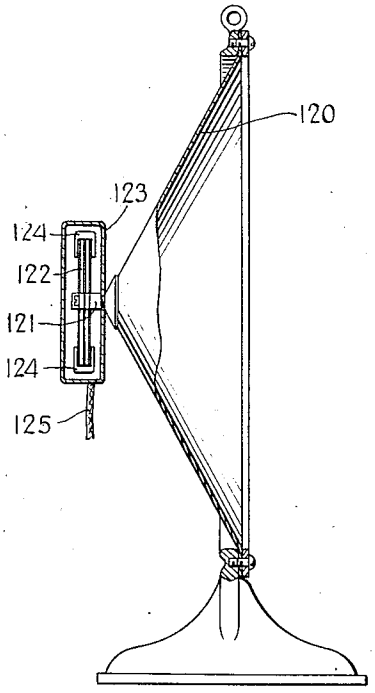
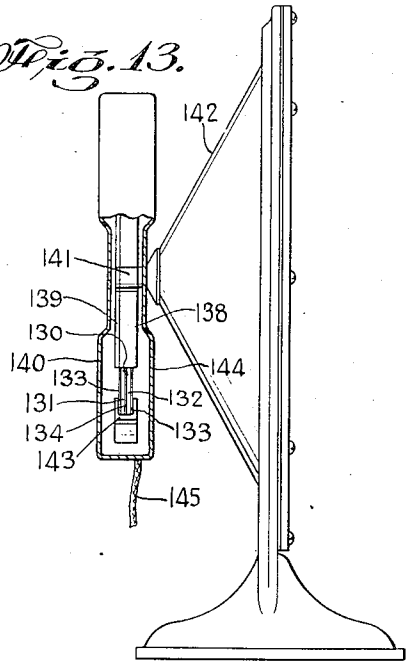


Fig. 13.



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Patented June 23, 1936 2,045,404

UNITED STATES PATENT OFFICE

2,045,404

PIEZOELECTRIC VIBRATOR DEVICE

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Application May 24, 1933, Serial No. 672,561

23 Claims. (Cl. 179—107)

This invention relates to piezo-electric vibrator devices and it has among its objects improvement of the energy transmission and increase of the low frequency vibration output of the same.

Special objects of the present invention are piezo-electric sound apparatus, and particularly hearing-aid bone vibrator devices with improved vibratory power transmission and increased low frequency output.

The foregoing and other objects of my invention will be best understood from the following description of exemplifications thereof, reference being had to the accompanying drawings, wherein

Fig. 1 is a vertical cross sectional view through a bone vibrator unit;

Fig. 2 is a horizontal sectional view along line 2—2 of Fig. 1;

Fig. 3 is a vertical sectional view of a modified form of bone vibrator;

Fig. 4 is a vertical sectional view of Fig. 3 along line 4—4;

Fig. 5 is a horizontal sectional view of the bone vibrator of Figs. 3 and 4 along line 5—5 of Fig. 3;

Fig. 6 is a view of the bone vibrator device as carried on the head of a person;

Fig. 7 is a circuit diagram of a bone-conduction hearing-aid device utilizing the bone vibrator;

Fig. 8 is a vertical sectional view of a telephone receiver embodying the invention;

Fig. 9 is a horizontal sectional view through the coupling connection between the vibrator and the diaphraghm of the telephone receiver of Fig. 8 along line 9—9;

Fig. 10 is an elevational view partially in section illustrating a spectacle frame with a bone vibrator unit in accordance with the invention, the front cover of the vibrator chamber being removed;

Figs. 11, 12 and 13 are elevational views partially in section of loud speakers embodying modifications of the invention; and

Fig. 14 is a detailed view of the vibrator unit of Fig. 13 as seen from the left side of Fig. 13.

In my copending application on piezo-electric devices, Serial No. 672,560, filed concurrently with the present application, I have described improvements in sound producing devices driven by piezo-electric vibrator units, and particularly Rochelle crystal vibrator units. Vibrator units made by uniting crystal plates or strips of highly piezo-electric crystal substances, such as Rochelle salt crystals, have been chiefly used in this field.

One type of vibrator unit, known as "twister" consists of two flat X-cut plates of Rochelle salt crystal, or similar piezo-electric substance, mechanically united to each other along a common junction face, with electrode sheets attached to the faces for applying thereto electric fields tending to impart to the two adjacent plates oppositely directed deformations, restraining one plate by the other, and producing a resulting bending motion of the unit larger than the motion that would be imparted to said crystal plates in unrestrained condition.

The other type of vibrator unit known as "bender" consists of two flat crystal 45°-X-cut bars (cut from a Rochelle salt crystal plate perpendicular to the electrical X-axis under an angle of 45° against the optical axis Z) mechanically united to each other along a common junction face, with electrode sheets applied to the faces for impressing upon the crystal bars electric fields tending to impart longitudinal expansion to one bar while imparting longitudinal contraction to the adjacent other bar and thus mutually restraining their longitudinal movements and causing the united bars to bend in a direction perpendicular to the faces with a greater motion than could be obtained by the unrestrained independent longitudinal motions of the two bars.

Such twisters and benders reverse their deformations on reversal of the electric field applied to the individual crystal layers. By applying sound-frequency electrical oscillations to the electrode sheets on the faces of said crystals, alternating electric fields are impressed on the two crystal bars, imparting to the two-layer crystal unit a vibratory bending movement of a frequency corresponding to the impressed oscillations.

Such twisters and benders may be constructed either as two-layer units described above, or as four-, six- or multiple-layer units in which case, the adjacent faces of individual two-layer units are united to each other to act as a single unit with a multiple of the power of a two-layer unit. As used broadly herein, the terms "twister" and "bender" apply to two-layer units as well as to larger multiple-layer units.

Heretofore, loud speaker diaphragms, record cutters and similar acoustic instruments have been driven with such vibrator crystal units by clamping one end portion of such unit to a heavy mass to definitely locate one end of the unit in space, and coupling the load to which the vibrations are to be imparted to a vibrating end portion of the crystal unit having the largest amplitude, and thus utilizing the vibratory motion of

the unit for imparting vibratory energy to the coupled load.

While it is relatively easy to impart to a vibratory load high frequency vibrations of several thousand cycles by means of a piezo-electric vibrating unit, the amount of low frequency vibratory energy that can be imparted with such vibrating unit greatly decreases with the decrease of the frequency and very little of such energy can be transmitted at frequencies of several hundred cycles per second important for speech and music reproduction, and in hearing-aid devices. Since Rochelle salt crystals have a much greater piezo-electric effect than other available piezo-electric substances, Rochelle salt vibrator units are able to deliver more vibratory power at low frequencies than vibrator units made of the other crystal materials. But even with Rochelle salt crystal vibrators as heretofore known, the amount of low frequency vibration energy that can be imparted to an acoustic load is relatively small, thus making difficult practical sound producing devices of good quality.

This difficulty is particularly great in case of bone vibrators for bone-conducton hearing-aids which must be made very small in order to permit their inconspicuous wear on the head of the user, thus restricting the size of the crystal to small dimensions making impossible transfer of large vibratory power.

I have found that the difficulties of producing sufficient low frequency vibrations and transferring the same with a small crystal vibrating unit to an acoustic load car be overcome by a special construction and mounting of the crystal vibrating unit and utilization of the reactive forces produced by the vibrator unit during its vibration.

In accordance with the invention, I mount the crystal unit on a relatively light support of little weight and small inertia and utilize the reactive forces produced in the support by intensive vibration of the crystal vibrator unit for imparting corresponding vibrations to the acoustic load that is driven by the crystal unit.

A simple small-size bone vibrator for a bone-conduction hearing-aid device made in accordance with my invention is shown in Fig. 1 of the drawings. The vibrator unit is in the form of a bender bar **20**, made by uniting to each other two 45°-X-cut Rochelle salt crystal bars **21**, **22** as explained in my copending application identified above. To the outer faces of the bar **20** are secured electrode sheets **23**, **24** and an intermediate electrode sheet **25** is provided at the junction of the two crystal surfaces, these electrode sheets being of thin metal and being intimately united with the faces of the crystal strips to consume only little of the potential drop available for producing an electric field through the crystal bars. Because of the requirement that the vibrator be inconspicuous, very small crystals are used in the vibrator unit, the size of the individual crystals being about 1½ x ⅜ x $\frac{1}{16}$ of an inch.

At its lower end the flat portion of the crystal unit bar **20** is clamped against a clamping member **26** comprising two metallic clamping blocks **27** and **28** secured to a mass of rigid insulating material such as Bakelite. A clamping cavity **29** is formed between the two metallic clamping members **27**, **28** into which the lower flat end of the vibrator bar **20** is fitted, a clamping bar **30** held pressed to the blocks **27**, **28** by means of screws **31** holding the vibrator bar in place. To prevent nonuniform pressure at the clamping surfaces,. layers **32** of yieldable material are interposed between the clamping members and the clamped portions of the crystal faces. Electrode sheets **33** on the outer surfaces of the crystal bars and the intermediate electrode sheet **34** are connected to the blocks **27** and **28**, respectively, through the contact strips **35** and the contact strip **36**, respectively. Electrical oscillations are supplied to the electrode sheets **33**, **34** by means of plug pins **37** inserted into perforations **38** extending from the bottom side of the contact blocks **27** and **28**, the plug pins being connected to a conductor cord **39** leading to a source of electric sound-frequency oscillations, such as the output of an audio amplifier of a hearing-aid or radio broadcasting receiver.

To the upper free end of the vibrating crystal bar **20** is attached a weight **40**, of lead, for instance, having an interior cavity providing a portion fitting tightly and attached to the end of the crystal bar and an additional projecting skirt-like portion for accommodating additional weight without clamping additional crystal surface, a free space **41** being provided above the upper end surface of the crystal bar.

The clamping member **26** has an upwardly extending projecting wall **45** having a slightly elevated contact portion **46** which may be applied to the bone structure of the head for transferring vibratory power thereto. To the front side of the clamping block **30** is secured, as by screws, the lower end of a flat gripping member **47** connected to the end of a head band **48** by means of which the vibrator unit with its mounting may be held on the head of a person having impaired outer hearing organs, and pressed against the bone structure, such as the mastoid bone.

With the vibrator held against the bone structure and the electrode sheets of the crystal unit connected through cord **39** to a source of electric sound-frequency oscillations, sound vibrations will be imparted to the upwardly projecting crystal bar **20** of the vibrating unit, these vibrations containing a relatively large amount of low frequency vibration energy because of the additional weight **40** attached to the vibrating crystal bar **20**. Since the clamp holding the lower end of the crystal bar is relatively light, the reactions of the bar impart through the clamp **26** and the contact member **46** extending therefrom vigorous vibrations to the bone structure engaged by it. This reactive coupling of the vibrator with the bone structure secures efficient transmission of the vibratory energy produced by the vibrator unit to the bone structure of the head without the necessity of coupling buttons or other special coupling connections to the vibratory portion of the bar and without in any way restraining the free vibration thereof. The mounting of the crystal unit is thus simplified and more efficient transfer of energy secured.

With the reactive coupling it is easy to provide a coupling connection between the clamping member and the bone structure of the head at which a good impedance match is secured between the vibrator unit and the head structure, thus enabling an increase of the amount of low frequency vibrations transmitted to the bone structure without the difficulties of getting direct matched coupling with the vibratory portion of the crystal unit.

The increased amount of low frequency vibratory energy secured by the additional weight 40 attached to the vibratory portion of the crystal is thus increased by the reactive coupling of the crystal bar to the bone structure and the resulting vibrations of the free bar.

While the vibrator unit shown in Figs. 1 and 2 is very convenient for observing and studying the reaction-type bender unit, I prefer to enclose it completely in a casing for practical use as a hearing-aid bone vibrator. This is greatly facilitated by the fact that no coupling connections are required between the vibratory portion of the vibrator unit and the bone structure. Such bone vibrator is shown in Figs. 3 to 5 in which the vibrating bender crystal bar 20 is clamped in the interior of a small casing 51 to the metallic clamping blocks 27 and 28, imbedded in and rigidly held by the interior of the casing wall 52 which has on its rear side an elevated portion 53 constituting the contact surface engaging the bone structure of the head of the user.

The vibrating portion of the crystal vibrator unit 20 is weighted at the top, and its lower end is clamped in the same way as in the arrangement shown in Fig. 1, and the connection to its electrode sheets is made by plug pins and cord likewise in the same way. The rear side of the casing has an opening 61 through which the crystal unit is inserted into the casing and properly clamped therein. The casing opening is closed by a sheet cover 62 which has attached thereto a second sheet member 63 of the same size having formed in its lower portion a channel 64 for engaging the flat end 65 of a gripping member 66 connected to a head band 67 by means of which the unit is supported on the head and held pressed with its contact surface 53 against the bone structure, such as the mastoid bone, as shown in Fig. 6. The two cover sheets 62 and 63 are suitably secured to the casing, for instance, by screws 68 and completely enclose the vibrator unit so that the vibrator is protected against contact with the body of the person and against disturbances from the exterior. By making the junction between the cover and the casing sufficiently tight, entrance of moisture into the interior casing may be positively prevented and its operativeness under all operating conditions maintained. Sufficient space is provided in the chamber for permitting free vibration of the vibrating unit under the forces induced therein by the applied electric fields.

Through the reactive coupling of the vibrating unit with the head structure, which is exactly like that explained in connection with Fig. 1, it will transfer a large amount of vibratory energy to the bone structure of the user without requiring any coupling between the vibratory portion of the crystal unit and the head. Enough low frequency will be produced, and transferred from the vibrator to the head because of the additional load attached to the vibrating crystal bar section and due to the good impedance match between the crystal vibrator and the bone structure.

To actuate the vibrator unit, it may be supplied with electric sound-frequency oscillations either from the output circuit of an amplifier of a radio or phonograph instrument, or from a special sound transmitting apparatus as shown in Fig. 7. The apparatus comprises a transmitting microphone 70 connected through a cord 71 in the input circuit of an amplifying device 72 to produce current oscillations from battery 73 in accordance with the sound vibrations impinging on the diaphragm of the transmitting microphone 70. The produced oscillations are amplified in the amplifier 72 and are supplied from the output thereof through a rheostat 74 and a transformer 75 to the two leads 37 which are connected with the electrode sheets 23 and 24 of the vibrator unit 20. Such small crystal vibrator will satisfactorily reproduce sound when operated with an oscillation source applying about 10 volts to the individual crystal plates.

The weight of the crystal parts without the additional weight is about 2½ grams, and the total vibrator units with the casing weighs only about 16 grams. The completely assembled bone vibrator as shown in Figs. 3 to 5 is about 1¾" long, about ¾" wide, and about ⅜" thick, being small and inconspicuous when worn on the head of a person, for instance, against the mastoid bone. Many persons of impaired hearing do not mind carrying the hearing-aid on a lorgnette handle as long as the weight of the hearing-aid is small. The vibrator made according to the invention, as shown in Figs. 3 to 5, is particularly light and suitable for use with a lorgnette handle by inserting a flat strip mounted on its upper end into the channel 64 provided for carrying it with the head band.

In Figs. 8 and 9 my invention is shown applied to a telephone receiver. It comprises a diaphragm 81 in the form of a circular thin metal sheet held at its edges between two washers 82 which are clamped between the shoulder 83 of an enclosing casing and the annular projecting portion 84 of the cover 85. The center of diaphragm 81 is connected to a coupling clamp 88 which embraces and clamps firmly the center portion of a crystal unit 89 like bender 20 shown in Figs. 1 to 5, but smaller in size. The crystal unit 89 is preferably made of Rochelle salt crystal strips and provided with electrode sheets and electrical connections therefrom to a lead 90 in a way similar to the bender shown in Figs. 1 to 5. Instead of clamping the crystal unit at one end, it is clamped in the center so that the two oppositely projecting bar portions extending from the clamp vibrate in synchronism between positions at which they approach the diaphragm 81 and positions at which they move away therefrom. The clamp 88, shown in detail in Fig. 9, comprises a pair of clamping members 91 embracing the flat crystal faces and clamped thereto by screws 92, resilient layers 93 on the clamped portions of the crystals serving to equalize the clamping pressure. One of the clamping members is connected by a coupling rod 94 to the center of the diaphragm 81 and is connected thereto by clamping members 95 so that the two vibrator bars of the crystal unit 89 project on the opposite sides of the clamp 88 and are carried by the center of the diaphragm 81, being free to vibrate like two individual benders. Weights 96 are attached to the ends of the two vibrating bars like to the bender 20 of Fig. 1.

Upon energization of the crystal unit by connecting its leads 90 to a source of vibratory electric sound-frequency oscillations, a vibratory bending movement will be imparted to the two projecting bender members extending from the clamp 88, the vibrating units swinging in synchronism back and forward and transferring their vibratory energy to the diaphragm 81 through the reactive coupling connection between

the clamp 88 with the diaphragm 81 like the coupling connection between the bender clamp and the bone structure in the bone vibrator of Fig. 1.

An efficient and simple telephone receiver is thus obtained which gives a sound output having enough low as well as high frequency sound oscillations to permit good reproduction of speech and music.

In Fig. 10 is shown a piezo-electric crystal unit like that used in the telephone of Fig. 8 for imparting bone vibrations to the head bone structure through the nasal bone. To this end, a spectacle frame 100 is provided with a bridge member 101 forming a chamber 102 in which is mounted a bender crystal unit 103 similar to the bender 89 of Fig. 8, the chamber being normally closed by a cover which fits the chamber opening. The bender is weighted with weights 104 at its ends and is held clamped at the center by a clamp 105 which is attached to the lower bridge wall 106 extending between the frame portions 107 which rest on the nasal bone of the wearer of the spectacle, the clamp 105 being constructed like the receiver clamp 88. Bending vibrations are imparted to the two projecting weighted bender portions by supplying to their electrode sheets sound-frequency oscillations through a cord 108 mounted in the spectacle frame. These vibrations are reactively transmitted through the coupling member 105 and the lower bridge wall 106 to the contact portions 107 engaging the nasal bone. The vibratory energy of the pair of benders within the bridge chamber is thus transferred through the reaction forces acting on the coupling member to the bone structure of the spectacle wearer in a way similar to the action of the double bender in the telephone of Fig. 8.

Fig. 11 shows a cone speaker driven by reactive coupling with a double bender in accordance with my invention. The speaker cone 110 has its front end supported on a bracket 111 which is attached to a casing 112 having a relatively heavy support 113. Attached to the center of the cone 110 on the side facing the interior of casing 112 is a clamp member 114 similar to the clamp 88 of the telephone vibrator, but of suitable larger size, clamping the center portion of a relatively long bender unit 115 having weights 116 attached to its opposite vibrating ends. Additional flexible support is supplied to the junction of the cone center and to the bender coupled thereto by a flexible sheet 118.

Electrical sound-frequency oscillations supplied to the electrode sheets of the bender unit 115 through cord 117 impart a synchronous vibration of the two bender halves and the reactive forces exercised thereby on the clamp 114 cause transfer of vibratory energy to the cone 110 imparting thereto a vibratory movement producing a large volume of sound rich in low frequencies.

In Fig. 12 there is shown another modification of the invention in which a somewhat smaller cone 120 has attached to its center portion a clamp 121 holding a double bender vibrator unit 122 like that of the structure of Fig. 11 and a light casing 123 enclosing the vibrator unit and its additional weight members 124, the weight of the vibrator unit being sufficiently small not to place an excessive strain on the cone. By impressing sound-frequency oscillations on the electrode sheets of the bender unit 122 through a suitably connected cord 125, the two weighted bender portions of the crystal unit 122 are set into a synchronous vibration and the reactive forces exercised by the vibratory motion reacts through the coupling clamp 121 on the cone, imparting to it vibratory energy rich in low frequencies.

In the modification of the invention shown in Figs. 13 and 14, a cone loud speaker constructed similar to the speaker shown in Fig. 12 is actuated by the reactive forces of a pair of twister units 130, referred to hereinbefore, and made in the way disclosed in my copending application on Piezo-electric devices, Ser. No. 672,560, filed concurrently herewith. Each twister unit 130 comprises two rectangular crystal plates 131 and 132 cut from a Rochelle salt crystal perpendicular to the electric axis and united to each other, and with interior and exterior electrode sheets 133, 134 connected to produce bending of the diametrically opposite corners in opposite directions when in unclamped condition. Two adjacent edges 135, 136 of each crystal unit are clamped to a cross-shaped rigid supporting member 138 by means of clamping plates 139, insulating yieldable layers 140 of fibre being interposed at the clamping surfaces. The center part 141 of supporting member 138 is attached to the center of a cone 142 to transmit reactive vibratory forces impressed by the vibrating action of the twister units 130 upon the supporting member 138 on the cone 142 and impart corresponding vibrations thereto. The unclamped corner of each twister unit has attached thereto a weight 143, and the entire vibrator unit is enclosed in a casing 144. The small weight of the crystal makes further support of the vibration imparting structure unnecessary. By impressing through leads from a source of electric sound-frequency oscillations going through cord 145 to the insulated electrode sheets 133 and 134, respectively, oscillations on the two twister units 130, vibratory motion is imparted thereto and the reactive forces developed by the crystal unit act through the central member 141 on the cone 142 impressing thereon vibrations producing sound rich in low frequencies.

The principles underlying the invention may be utilized in many other ways that will suggest themselves to those skilled in the art, and it is accordingly desired that the appended claims be given a broad construction commensurate with the invention.

I claim:

1. In a piezo-electric device for imparting mechanical vibrations to a load, a vibrator comprising a member of piezo-electric crystal substance, electrode means for impressing electric oscillations on the piezo-electric substance of said member to produce a vibratory motion of said vibrator, and coupling means supporting said vibrator in a floating condition and coupling said vibrator to a load to cause transfer of vibratory energy produced by said vibratory motion to said load.

2. In a piezo-electric device for imparting mechanical vibrations to a load, a vibrator including a layer of piezo-electric crystal substance, electrode means for impressing electric oscillations across said crystal layer inducing therein alternating forces tending to impart opposite longitudinal deformations to said layer, means restraining said crystal layer against longitudinal deformation and imparting under the action of said forces a vibratory bending motion to said vibrator, and coupling means supporting said vibrator in a floating condition and coupling said vibrator to a load

to cause transfer of vibratory energy produced by said vibratory motion to said load.

3. In a piezo-electric device for imparting mechanical vibrations to a load, a vibrator comprising a member of piezo-electric substance, electrode means impressing electric oscillations on the piezo-electric substance for producing a vibratory motion between two parts of said vibrator, and supporting means for coupling one part of said vibrator to a load and supporting in a floating condition the other part of said vibrator having a sufficient floating mass exerting reaction forces for imparting vibratory energy to said load.

4. In a piezo-electric device for imparting mechanical vibrations to a load, a vibrator comprising a member of piezo-electric substance, electrode means impressing electric oscillations on the piezo-electric substance for producing a vibratory motion between two parts of said vibrator, and supporting means for coupling one part of said vibrator to a load and supporting in a floating condition the other part of said vibrator having a sufficient floating mass of the order or larger than one-half of the mass of the vibrator exerting reaction forces for imparting vibratory energy to said load.

5. In a piezo-electric device for imparting mechanical vibrations to a load, a vibrator comprising a member of piezo-electric substance, electrode means impressing electric oscillations on the piezo-electric member for producing a vibratory motion between two parts of said vibrator, and supporting means for coupling one part of said vibrator to a load and supporting in a floating condition the other part of said vibrator having a sufficient floating mass exerting reaction forces perpendicular to the longitudinal direction of the vibrator for imparting vibratory energy to said load.

6. In a piezo-electric device for imparting mechanical vibrations to a vibratory load, a vibrator comprising a member of piezo-electric crystal substance, electrode means for impressing electric oscillations across said crystal member inducing therein alternating forces producing a vibratory motion between two sections of said vibrator, and coupling means supporting said vibrator and holding one of said sections mechanically restrained and coupled to said load, the other section of said vibrator being supported in a freely vibrating floating condition for producing during vibration reactive forces transmitting vibratory energy to said load.

7. In a piezo-electric device for imparting mechanical vibrations to a load, a vibrator comprising a member of piezo-electric substance, electrode means impressing electric oscillations on the piezo-electric member for producing a vibratory motion between two parts of said vibrator, and supporting means for coupling one part of said vibrator to a load and supporting in a floating condition the other part of said vibrator having a sufficient floating mass of the order or larger than one-half of the mass of the vibrator exerting reaction forces perpendicular to the longitudinal direction of the vibrator for imparting vibratory energy to said load, said floating part of the vibrator including a body of substantial mass of greater specific weight than said piezo-electric substance.

8. In a piezo-electric device for imparting mechanical vibrations to a load, a vibrator comprising a member of piezo-electric substance, electrode means impressing electric oscillations on the piezo-electric member for producing a vibratory motion between two parts of said vibrator, and supporting means for coupling one part of said vibrator to a load and supporting in a floating condition the other part of said vibrator having a sufficient floating mass exerting reaction forces for imparting vibratory energy to said load, said floating part of the vibrator including a body of substantial mass of greater specific weight than said piezo-electric substance.

9. In a piezo-electric device for imparting mechanical vibrations to a load, a vibrator comprising a member of piezo-electric substance, electrode means impressing electric oscillations on the piezo-electric member for producing a vibratory motion between two parts of said vibrator, supporting means for coupling one part of said vibrator to a load and supporting in a floating condition the other part of said vibrator having a sufficient floating mass exerting reaction forces for imparting vibratory energy to said load, and a casing extending from the coupled part of the vibrator and enclosing the floating part of the vibrator.

10. In a piezo-electric device for imparting mechanical vibrations to a load, a vibrator comprising a member of piezo-electric substance, electrode means impressing electric oscillations on the piezo-electric member for producing a vibratory motion between two parts of said vibrator, supporting means for coupling one part of said vibrator to a load and supporting in a floating condition the other part of said vibrator having a sufficient floating mass of the order or larger than one-half of the mass of the vibrator exerting reaction forces for imparting vibratory energy to said load, and a casing extending from the coupled part of the vibrator and enclosing the floating part of the vibrator.

11. In a piezo-electric device for imparting mechanical vibrations to a load, a vibrator comprising a member of piezo-electric substance, electrode means impressing electric oscillations on the piezo-electric member for producing a vibratory motion between two parts of said vibrator, supporting means for coupling one part of said vibrator to a load and supporting in a floating condition the other part of said vibrator having a sufficient floating mass exerting reaction forces perpendicular to the longitudinal direction of the vibrator for imparting vibratory energy to said load, and a casing extending from the coupled part of the vibrator and enclosing the floating part of the vibrator.

12. In a piezo-electric device for imparting mechanical vibrations to a load, a vibrator comprising a member of piezo-electric substance, electrode means impressing electric ocillations on the piezo-electric member for producing a vibratory motion between two parts of said vibrator, supporting means for coupling one part of said vibrator to a load and supporting in a floating condition the other part of said vibrator having a sufficient floating mass exerting reaction forces for imparting vibratory energy to said load, said floating part of the vibrator including a body of substantial mass of greater specific weight than said piezo-electric substance, and a casing extending from the coupled part of the vibrator and enclosing the coating part of the vibrator.

13. In a piezo-electric acoustic device for imparting mechanical vibrations to an acoustic load, a vibrator comprising a member of piezo-electric Rochelle salt crystal substance, electrode means impressing sound-frequency electric oscillations on said piezo-electric member for producing a

vibratory motion between two parts of said vibrator, and supporting means for coupling one part of said vibrator to a load and supporting in a floating condition the other part of said vibrator having a sufficient floating mass exerting reaction forces for imparting vibratory energy to said load.

14. In a piezo-electric acoustic device for imparting mechanical vibrations to an acoustic load, a vibrator comprising a member of piezo-electric Rochelle salt crystal substance, electrode means impressing sound-frequency electric oscillations on said piezo-electric member for producing a vibratory motion between two parts of said vibrator, and supporting means for coupling one part of said vibrator to a load and supporting in a floating condition the other part of said vibrator having a sufficient floating mass exerting reaction forces for imparting vibratory energy to said load, said floating part of the vibrator including a body of substantial mass of greater specific weight than said crystal.

15. In a piezo-electric hearing-inducing bone-vibrator device, a vibrator of a size suitable for inconspicuous wear on a person comprising a member of piezo-electric substance, electrode means impressing sound-frequency electric oscillations on said piezo-electric member for producing a vibratory motion between two parts of said vibrator, and supporting means for coupling one part of said vibrator to hearing-inducing bone structure and supporting in a floating condition the other part of said vibrator having a mass exerting reaction forces for imparting hearing-inducing energy to bone structure of a person.

16. In a piezo-electric hearing-inducing bone-vibrator device, a vibrator of a size suitable for inconspicuous wear on a person comprising a member of piezo-electric substance, electrode means impressing sound-frequency electric oscillations on said piezo-electric member for producing a vibratory motion between two parts of said vibrator, and supporting means for coupling one part of said vibrator to hearing-inducing bone structure and supporting in a floating condition the other part of said vibrator having a mass of the order of one-half of the mass of the vibrator or larger exerting reaction forces for imparting hearing-inducing energy to bone structure of a person.

17. In a piezo-electric hearing-inducing bone-vibrator device, a vibrator of a size suitable for inconspicuous wear on a person comprising a member of piezo-electric substance, electrode means impressing sound-frequency electric oscillations on said piezo-electric member for producing a vibratory motion between two parts of said vibrator, and supporting means for coupling one part of said vibrator to hearing-inducing bone structure and supporting in a floating condition the other part of said vibrator having a mass of the order of one-half of the mass of the vibrator or larger exerting reaction forces perpendicular to the longitudinal direction of the vibrator for imparting hearing-inducing energy to bone structure of a person.

18. In a piezo-electric hearing-inducing bone-vibrator device, a vibrator of a size suitable for inconspicuous wear on a person comprising a member of piezo-electric substance, electrode means impressing sound-frequency electric oscillations on said piezo-electric member for producing a vibratory motion between two parts of said vibrator, and supporting means for coupling one part of said vibrator to hearing-inducing bone structure and supporting in a floating condition the other part of said vibrator having a mass exerting reaction forces perpendicular to the longitudinal direction of the vibrator for imparting hearing-inducing energy to bone structure of a person, said floating part of the vibrator including a body of substantial mass of greater specific weight than said piezo-electric substance.

19. In a piezo-electric hearing-inducing bone-vibrator device, a vibrator of a size suitable for inconspicuous wear on a person comprising a member of piezo-electric substance, electrode means impressing sound-frequency electric oscillations on said piezo-electric member for producing a vibratory motion between two parts of said vibrator, supporting means for coupling one part of said vibrator to hearing-inducing bone structure and supporting in a floating condition the other part of said vibrator having a mass of the order of one-half of the mass of the vibrator or larger exerting reaction forces perpendicular to the longitudinal direction of the vibrator for imparting hearing-inducing energy to bone structure of a person, and a casing extending from the coupled part of the vibrator and enclosing the floating part of the vibrator.

20. In a piezo-electric device for imparting mechanical vibrations to a load, a vibrator comprising a member of piezo-electric crystal substance, electrode means for impressing electric oscillations on the piezo-electric substance of said member producing a vibratory motion of said vibrator, coupling means supporting said vibrator in a floating condition and coupling a portion of said vibrator to a load for imparting vibratory energy produced by said motion to said load, and a body of substantial mass of greater specific weight than said crystal attached to the floating part of said vibrator.

21. In a piezo-electric device for imparting mechanical vibrations to a load, a vibrator comprising a member of piezo-electric crystal substance, electrode means for impressing electric oscillations on said crystal member producing a vibratory motion thereof, coupling means supporting said vibrator in a floating condition and coupling a portion of said vibrator to a load for imparting vibratory energy produced by said motion to said load, the floating part of said vibrator including a body of substantial mass of greater specific weight than said crystal casing extending from said coupling means and enclosing the floating part of said vibrator.

22. In a piezo-electric energy translating device, a vibratory structure comprising a member of piezo-electric substance, electrode means associated with said piezo-electric substance for translating electric energy oscillations applied to said substance into mechanical vibrations of said vibratory structure and vice versa, and means coupling a part of said vibratory structure to an external vibratory body and supporting another part of said vibratory structure having a substantial mass subjected to the action of said electrode means in a freely floating position for transmitting by the inertia reaction of said floating vibratory structure vibratory energy between said vibratory structure and said vibratory body, the floating mass of said vibratory structure being of the order or larger than one-half of the total mass of said vibratory structure.

23. In a piezo-electric energy translating device, a vibratory structure comprising a member

of piezo-electric substance, electrode means associated with said piezo-electric substance for translating electric energy oscillations applied to said substance into mechanical vibrations of said vibratory structure and vice versa, and means coupling a part of said vibratory structure to an external vibratory body and supporting another part of said vibrator having a mass subjected to the action of said electrode means in a freely floating position for translating by the inertia reaction of said floating vibratory structure vibratory energy between said vibrator and said vibratory body, the floating mass of said vibratory structure including a body of greater specific weight than said piezo-electric substance being of the order or larger than one-half of the total mass of said vibratory structure.

EMMANUEL CHRIST NICHOLIDES.