Jan. 11, 1944. H. W. KOREN 2,339,173

BONE CONDUCTION RECEIVER

Filed Oct. 14, 1940 2 Sheets-Sheet 1

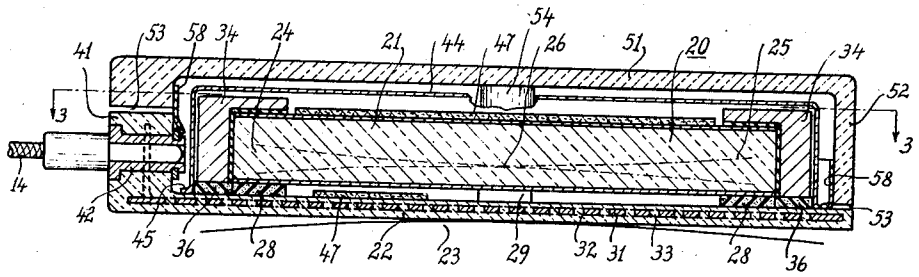
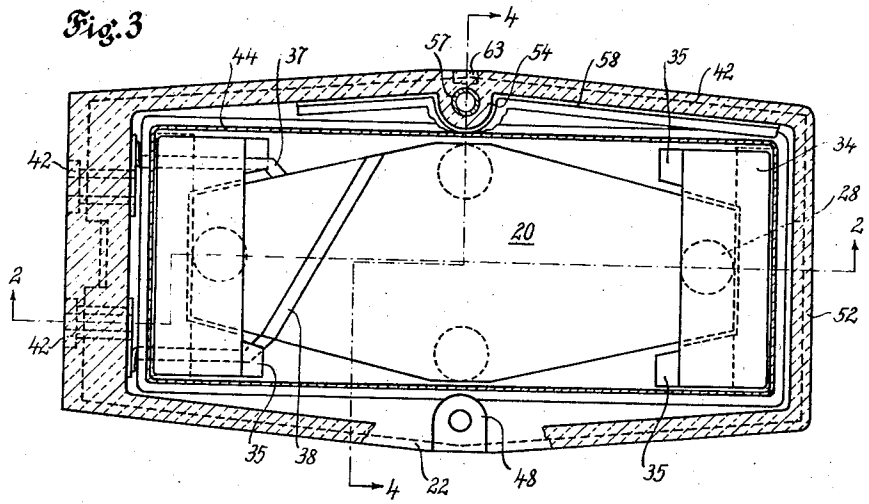



Fig. 2

Fig. 3



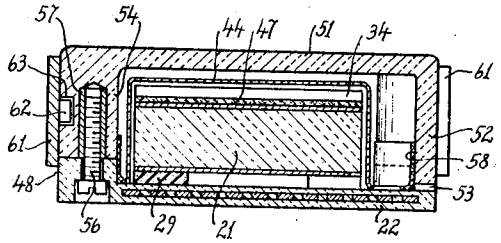
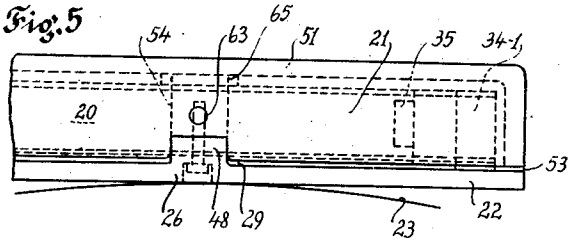




Fig. 4

Fig. 5



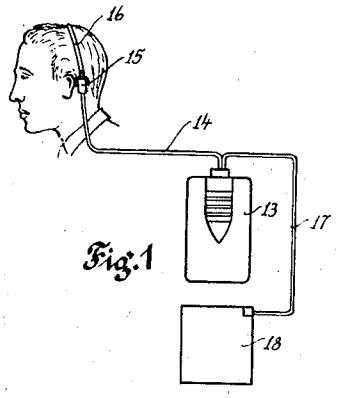




Fig. 1

INVENTOR

Heiman W. Koren

BY S. Michael Pineles

ATTORNEY

Jan. 11, 1944. H. W. KOREN 2,339,173

BONE CONDUCTION RECEIVER

Filed Oct. 14, 1940 2 Sheets-Sheet 2

Fig. 6

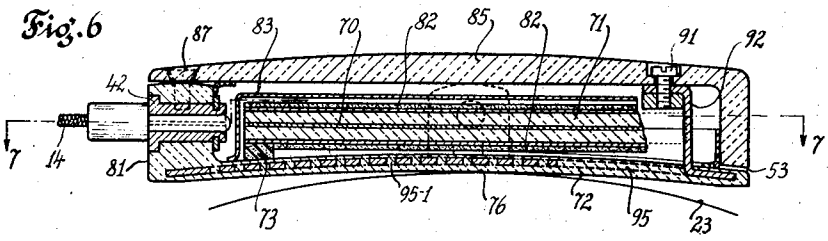



Fig. 7

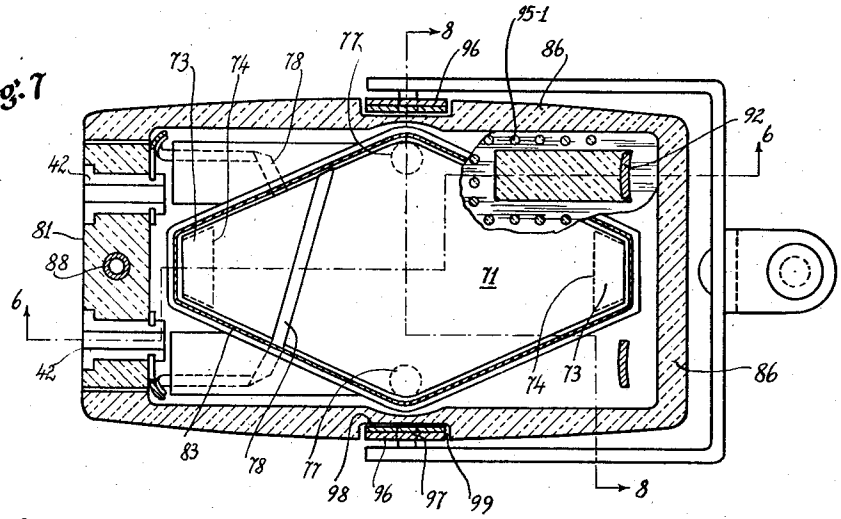
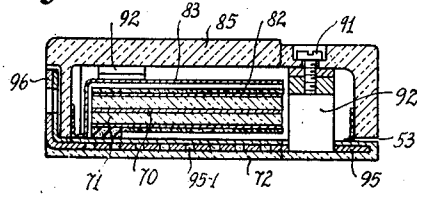



Fig. 8




INVENTOR
Heiman W. Koren
BY S. Michael Pinales
ATTORNEY

Patented Jan. 11, 1944

2,339,173

# UNITED STATES PATENT OFFICE

2,339,173

## BONE CONDUCTION RECEIVER

Heiman W. Koren, Bronx, N. Y., assignor to Sonotone Corporation, Elmsford, N. Y., a corporation of New York

Application October 14, 1940, Serial No. 361,140

7 Claims. (Cl. 179—107)

This invention relates to bone conduction hearing aids small enough for inconspicuous wear on the body of the user, and more particularly to bone conduction receivers for such hearing aids which are light enough for comfortable and inconspicuous wear in contact with a hearing inducing bone of the head, and are efficient enough for imparting to the bones the vibratory energy required for transmitting sound vibrations through the bones of the head to the hearing nerves of the inner ear and induce intelligible hearing of speech and music.

Among the objects of the invention is such inconspicuously small wearable hearing aid bone conduction receiver formed essentially of a plate or strip-like piezo-electric crystal unit, at least one side of which is united, as by cementing, to a mechanically strong, elastically compliant bone-contact wall to form therewith a mechanically strong vibrating structure which vibrates under the action of electric speech-frequency oscillations applied to the crystal unit, and which is so arranged that by holding one portion against a hearing inducing bone, the vibratory action of its other portion will exert on the bones inertia reaction forces sufficient for imparting thereto hearing inducing vibrations of large intensity and small amplitude required for inducing intelligible hearing of speech by bone conduction.

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

Fig. 1 is a diagrammatic view of a wearable bone conduction hearing aid employing a bone conduction receiver of the invention;

Fig. 2 is a vertical cross-sectional view along line 2—2 of Fig. 3 of a bone conduction receiver exemplifying the invention;

Fig. 3 is a horizontal cross-sectional view along line 3—3 of Fig. 2;

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

Fig. 5 is a side view of a modified form of bone conduction receiver of the invention; and

Figs. 6 to 8 are views similar to Figs. 2 to 4, respectively, illustrating another exemplification of a bone conduction receiver of the invention.

The bone conduction receivers of the invention are designed for operation as a part of a wearable hearing aid small enough for inconspicuous wear on the body of the user, of the general type described in the copending application Ser. No. 418,857, filed November 12, 1941, as a continuation-in-part of the application Serial No. 294,649, filed September 13, 1939, and assigned to the assignee of the present application. The general arrangement of such wearable hearing air is shown in Fig. 1. It comprises a flat compact amplifier casing 13 small enough for inconspicuous wear, for instance in the vest pocket of the user, the casing 13 housing a diaphragm driven Rochelle salt crystal microphone and an electron tube amplifier which amplifies the input of the microphone. The amplifier impresses the amplified microphone input through the leads of a receiver cord 14 on a bone conduction receiver 15 which is held by a head band 16, of spring steel, for instance, against a hearing inducing bone of the uses, such as the mastoid bone behind the ear. The amplifier is energized by an energy supply unit, shown in the form of a flat compact battery aggregate 17, which is connected to the amplifier casing through a battery cord 18 and is designed for inconspicuous wear hidden under the clothing of the user.

The bone conduction receiver 15, exemplifying one form of the invention, is shown in Figs. 2 to 4. It consists essentially of a vibrating structure 20 formed of a plate-like piezo-electric crystal vibrating member or unit 21, which is united, as by cementing, along a substantial portion of its length to a relatively thin, mechanically strong and shockproof, and elastically compliant strip or plate-like wall member 22, a portion of which is held pressed against a hearing inducing bone 23 of the user.

The piezo-electric crystal unit 21 is provided with foil electrodes secured to its faces and may embody one of the several types of designs described in the U. S. Patents 1,802,782, 1,803,274, 1,803,275 and 1,995,275. The resilient bone-contacting strip or wall 22 is combined with the piezo-electric unit 21 to form therewith a unitary mechanically strong and shockproof vibrating unit 20 which vibrates under the action of electric speech frequency voltages applied to the electrodes of the crystal unit. The vibrating structure 20 so formed is so arranged that when its bone-contacting portion is held against the bones, its resiliently carried vibratory portions 24, 25 form with the mass of the bones a vibratory system, and that the vibrations of its resiliently carried portions 24, 25, relatively to the bone-contacting portion 26, which serves as a nodal portion of the vibrating structure, exert thereon inertia reaction forces acting in a gen-

eral direction toward the bone-contacting surface and imparting therethrough to the bones vibrations of large intensity and small amplitude required for inducing intelligible hearing of speech by bone conduction.

Thus, for instance, the piezo-electric crystal unit 21 may be formed either of a single piezo-electric strip or bar which is cemented to the compliant contact plate 22 so as to form therewith a bender-type vibrating unit of the type described in Patent 1,803,274, or it may be formed of two piezo-electric crystal bars or plates joined into a bimorph of the type described in Patents 1,802,782 or 1,803,275, so as to vibrate either as a bender or twister, respectively. Two leads in the form of flat tin foil strips 27 extending from the electrode surfaces of the crystal unit 21 impress thereon the speech frequency voltage oscillations which impart to the vibratory structure 20 the desired vibratory motion.

In the form shown, the piezo-electric crystal unit 21 is of a flat double-trapezoidal shape, and only its center and its relatively narrow end portions are united across thin spacer-like junction elements 28, 29 to the compliant contact plate 22. The thin spacer elements 28, 29 are united to the facing surfaces of the crystal unit 21 and the contact plate 22 by a strong cementitious material, such as Vulcalock or Bakelite 6052 cement. The spacer elements 28, 29 are of a material, such as Viscoloid, which will flow and yield enough to prevent the exertion of abnormally large forces on the crystal unit 21 incident to the vibrations of the vibrating structure 20, while serving as a very good vibration propagating junction between the crystal unit and the resilient contact plate 22 so that the resulting vibrating structure 20 shall vibrate in the desired manner described above. One or more of the spacer elements 28, 29 may be made of a grade of neoprene which has properties similar to those of Viscoloid, neoprene being used, for instance, for the central junction elements 29, while the end spacer elements 28 are made of Viscoloid.

The bone contacting strip or wall 22 is preferably made of a sheet metal element 31 to which may be united an outer layer 32 of a suitable synthetic resin material, a thin coating of which may also be united to its inner surface facing the crystal unit. Alternatively, the resilient contact strip 22 may be made of a lamination formed of several layers of thin fabric or paper impregnated and united by a cementitious synthetic resin, such as a phenolic condensation product or some other integration-resistant resin.

The sheet metal element 31 of the contact plate 22 is provided with small perforations occupying a sufficient area and being so arranged as to keep the stiffness of the contact plate 22 sufficiently low and give it the required degree of resiliency. The perforations serve also as interlocking junctions with the layers of synthetic resin material united to the surfaces of the metal sheet 31, so as to permit the construction of the contact plate by a molding process. Alternatively, the contact plate 22 may be made of a thin lamination of thin fibrous sheets bonded with a synthetic resin.

In designing a vibrating structure 20 for an inertia reaction bone conduction receiver of the type described above, it is important to assure that when a portion of it is held coupled to the bones, the relatively small mass of its resiliently carried vibratory portion forms with the large mass of the bones a vibrating system which vibrates efficiently over the principal part of the speech frequency range when actuated by the output voltage of a hearing aid amplifier unit of the type referred to hereinabove.

To this end, the vibrating structure is designed so that when its contact portion is held coupled to the bones, the relatively small mass of its resiliently carried vibratory portions form with the relatively much larger mass of the bones of the head a vibrating system which has a resonant frequency in the principal part of the speech frequency range so that when it is actuated by speech frequency oscillations, it will give a good response over the speech frequency range, and it will impart to the bones inertia reaction forces sufficient to induce intelligible hearing of speech by bone conduction. The vibrating structure 20 may be given the desired resonant characteristics by uniting, as by cementing, to its two end portions 24, 25 suitable mass members 34 of material having a high specific gravity, such as lead. In the form shown, the mass members 34 embrace and are cemented to the narrow end portions 24, 25 of the crystal element 21 which are cemented to the adjacent portions of the contact plate 22. In order to accommodate the required mass, the mass members 34 may be provided with inwardly freely projecting extensions 35 which are free from engagement with the facing portions of the vibrating structure 20, so as not to increase its stiffness. The portions of the mass members 34 extending outwardly beyond the ends of the crystal element are united, as by cementing, to the underlying surface portions of the contact plate 22 either directly or across spacers 36 of a material, such as Viscoloid, for instance.

One end of the contact plate 22 is provided with a terminal block projection 41 in which are insulatingly mounted two terminal bushings 42 which are engaged by the plugs of the receiver cord 15 through which the electric speech frequency oscillations are impressed on the crystal element 21 of the receiver. The bushings may be of the type described in the copending application Serial No. 346,112, filed July 18, 1940, and their inner ends are connected to two tin foil lead strips 27 extending from the electrodes of the piezo-electric element. The tin foil lead strips 27 are shown folded flat along the surfaces of the crystal element 21 and along the underlying surface portions of the contact plate 22 leading to the terminal block, suitable insulating sheet elements, for instance, of cellulose acetate being placed above, and if required below, the tin foil strips so as to keep them insulated and protected against damage.

In order to protect the crystal element 21 against excessive humidity, a shell 44 of very thin moisture impervious foil, of aluminum, for instance, shaped to conform to the outline of the crystal element 21, is placed thereover, the lower flanged edges 45 of the shell 44 being cemented to the underlying surface of the contact plate 22 so as to form a moisture-proof enclosure around the vibrating crystal element. The shell 44 is made of material so thin and its surface is provided with corrugations so arranged that its effect in increasing the stiffness of the vibrating structure is negligible and substantially zero.

One or more pads 47 of moisture holding substance, such as leather, are shown placed inside the crystal enclosure formed by the shell 44 in

order to assure that the crystal does not become excessively dry and that the humidity conditions in the enclosure are conducive to the efficient operation of the crystal.

In order to protect the outer surface of the crystal element 21 against damage by external forces, a relatively rigid cover member 51 having side walls 52 extending downwardly toward the facing border portion of the contact plate 22 is mounted thereover. The edges of the side walls 52 are slightly spaced from the contact plate 22 by a gap 53 so as to permit the border portions of the contact plate to vibrate free from fringing engagement with the facing edge portion of the side walls 52 of the cover 51. The cover 51 is clampingly joined to the portion of the bone-contact plate 22 which is held pressed against the bone 23 and forms the nodal portion of the vibrating structure 20. To this end, the intermediate portions of the two cover side walls 52 lying above the nodal portions of the bone-contact plate 22 are provided with thickened wall portions 54 which are held clamped against similar upwardly extending mounting projections 48 of the contact plate 22, as by screws 56, engaging internally threaded bushings 57 embedded in the enlarged cover wall portions 54.

The gap 53 separating the downwardly facing edges of the side walls of the cover 51 from the contact plate 22 is sufficiently larger than the maximum vibration amplitudes to which the vibratory structure 20 may be subjected, to permit the vibrating structure 20 and its contact plate 22 to vibrate free from fringing engagement with the edges of the side walls 52 and any other portion of the cover 51, the gap 53 being at the same time sufficiently small so that when the vibrating end portions of the resilient contact plate 22 are pressed toward the casing cover 51 by an external force, the maximum bending deformation imparted to the crystal element will not exceed its elastic limit and will not bring about impairment or fracture of the crystal element. A gap spacing of the order of 5 to 10 mills will in general be satisfactory, the gap spacing depending on the length of the vibrating structure and the maximum amplitude of the vibrating structure.

There are also provided barrier means which prevent entrance of dust through the gap 53 into the interior of the space confined within the casing cover 51. To this end, a layer of yielding vibration non-absorbing and non-impeding material is placed across the gap 53 separating the edges of the cover from the boundaries of the contact plate.

In the arrangement shown, the dust barrier is formed by a strip 58 of close grained dust impervious fabric, such as silk or cotton, which is cemented to the inner surface portions of the cover 51 along the downwardly facing edges of its side walls 52, the strip 58 having skirt portions extending beyond the edges of the cover side walls and engaging the adjacent surface of the resilient contact plate 22, so as to overlap the peripheral gap 53 and prevent entrance of dust into the interior casing space.

Means are also provided for maintaining a good contact coupling connection between the nodal bone-contacting portion 26 of the vibrating structure 20 and the bone 23 against which it is held pressed, as by a head band 16. The head band may be of the type described in U. S. Patent 2,143,130 and one of its ends carries on a double swivel universal junction a U-shaped bracket, such as shown at 61 in Fig. 7, having arms provided with pivot pins 62 engaging pivot holes 63 formed in the thickened side wall portions of the cover 51 to which the nodal portion of the contact plate is clamped, so as to press the nodal bone-contacting portion 26 against the bone.

In Fig. 5 is shown a modified form of bone conduction receiver in which the mass members 34—1 which are used for giving the vibrating structure 20 the desired resonance characteristics is made only as thick as the crystal element 21, thereby reducing the overall thickness of the receiver to a minimum, determined only by the thickness of the crystal element 21. Since the nodal portion of the vibrating structure 20 and its crystal element 21 does not vibrate relatively to the cover, the overlying portion of the cover 51 may be united or clamped thereto, in the general way shown in Fig. 5. The inner surface portion of the cover 51 extending above the nodal bone-contacting portion of the vibrating structure 20 engages the underlying surface of the crystal element 21, a thin spacer 65, similar to the spacers 28, 29, being interposed between the crystal and the cover wall portion so as to permit clamping of the crystal element to the contact plate without exerting thereon an excessive pressure.

Since the terminal block 41 with the terminal elements carried thereby has a certain mass, the nodal bone-contacting portion 26 of the vibrating structure 20 at which the cover is held clamped to the contact plate 22 may be placed nearer to the terminal block so that the masses of the vibrating end portions of the vibrating structure 20 extending on both sides of the nodal bone-contacting portion 26 are balanced.

The nodal bone-contacting portion 26 of the vibrating structure 20 at which the resilient contact plate is clamped to the cover may also be located at an intermediate portion along the length of the vibrating structure 20 which is displaced from its mass center so that the portions of the vibrating structure extending in different directions from the nodal portion have different resonant characteristics and vibrate with different resonant characteristics.

Alternatively, the nodal bone-contacting portion 26 of the vibrating structure 20 which is pressed against the bones and which is held clamped to the cover 51 may be located on one of the end portions 24, 25 of the vibrating structure, in which case only one mass member, such as 34, having the required mass, is united to the other relatively freely vibrating end portion of the vibrating structure 20, so that when its bone-contacting end portion is held against the bones, the vibrating structure 20 forms with the mass of the bones a vibrating system having the desired resonant frequency at which it operates with a good response over the principal speech frequency range and imparts to the bones inertia reaction forces required for inducing hearing of speech by bone conduction.

Figs. 6 to 8 illustrate another form of bone conduction receiver based on the principles underlying the receiver shown in Figs. 2 to 5. Its essential part consists of a vibrating structure 70 formed of a plate-like piezo-electric unit 71 which is united as by cementing to a mechanically strong and shockproof and elastically compliant contact plate 72, a portion 73 of which is held pressed against a hearing inducing bone 23 of the user, as in the arrangements of Figs. 2 to 5.

The crystal element 71 is shown in the form of a bimorph which may be designed to operate either as a twister or bender. As in the previously described bone conduction receiver, the crystal element 71 has its two end portions 73 united to the facing surface portions of the contact plate 72 across thin spacer-like junction elements 74, and its two transverse corners are united to the resilient contact wall 72 by similar thin spacer-like junction elements 77. The junctions between the crystal element and the contact plate are so designed that when electric oscillations are applied through leads 78 to the electrode surfaces of the crystal element 71, while the contact portion 76 is held pressed against the bones 23, the end portions 73 of the vibrating structure 70, formed by the crystal element 71 and the contact plate 72 united thereto, will vibrate relatively to its intermediate portion which is coupled to the bones and exert thereon inertia reaction forces transmitting to the bones vibratory energy required for inducing hearing by bone conduction, as in the arrangement described in connection with Figs. 2 to 4. The resilient contact plate 72 is provided with a terminal block 81 and the crystal element 71 is enclosed by a humidity sealing enclosure 82 within which are located moisture holding pads 83, as in the arrangement of Figs. 2 to 4.

The vibrating unit 70 so formed of the crystal element 71 and the resilient contact plate 72 is given the desired resonant frequency characteristics which assure good response over the speech frequency range, not by the massive members 34, of the type described in connection with Figs. 2 to 5, but by combining a cover 85 with the crystal element, so as to give it the required resonance characteristics and serve also to protect the crystal element 71 against external mechanical forces.

In the form shown, the cover 85 forms a rigid structure having on three sides side walls 86 enclosing the space in which the crystal is confined. The free edge portion of the upper cover wall 85 is held clamped to the upwardly facing surface of the terminal block 81, as by a screw 87, threadedly engaging an internally threaded bushing 88 embedded in the terminal block.

The upper surface of the terminal block 81 is sufficiently curved and the surface of the hole in the cover plate 85 which is engaged by the head of the clamping screw 87 is so shaped as to permit limited tilting movement of the cover relatively to the terminal block 81. The other end of the cover is shown held clamped, as by screws 91, to the reinforced upper ends of upwardly projecting links 92 extending from the contact wall 72, the links being so shaped and arranged as to offer substantially negligible or zero resistance to forces exerted thereon in a direction parallel to the longer axis of the vibrating structure 70 and its crystal element, while providing a good coupling connection and substantially rigid junctions for forces transmitted in the direction of the links 92 between the contact plate 72 and the facing portion of the cover 85.

In other words, the cover 85 is so joined to the vibrating structure 70 formed by the crystal element 71 and the resilient contact plate 72 united thereto as to offer substantially zero resistance to small elongations and contractions of the vibrating structure 70 and its contact plate 72 in the direction of their length, while assuring that the mass of the cover 85 vibrates substantially in unison with the end portions of the vibrating structure 70 and its contact plate 72 in a direction generally perpendicular to the bone-contacting surface portion of the contact plate 72.

By this arrangement, the cover plate 85, which serves to protect the crystal unit against external mechanical forces is also utilized to serve as the additional mass required in order to give the vibrating structure 70 the desired resonant frequency characteristics in the principal part of the speech frequency range. The cover is designed with sufficient mass, as by making it partially or entirely of heavy metal, so that its mass is effective in giving to the vibrating unit 70 the required resonance characteristics.

The links 92 which serve as a junction between the contact plate 72 and the overlying portion of the cover 85 may be formed as separate units, the lower bent portions of which are united, as by riveting or spot welding, to the contact plate 72.

In the form shown, the links 92 are formed by cutting out and bending outward a strip portion of the metallic sheet element 95 forming one layer of the resilient contact plate 72, the other portions of the sheet metal layer 95 being provided with perforations 95—1 so as to give the contact plate 72 the desired resiliency.

In order to hold the contact plate portion 76 in good coupling engagement with the bone 23, the central part of its sheet metal element 95 is provided with two upwardly extending ear projections 96 having pivot holes 97 for receiving the pivot pins 62 of the head band bracket 61. The ear projections 96 are shown reinforced by a sheet metal backing element 98 and the side walls of the cover 85 are provided with recesses 99 in which the ears 96 are confined so that they do not project beyond the boundary of the cover side walls 86.

In the bone conduction receivers based on the principles of the invention, as explained above in connection with a specific exemplification thereof, the fragile crystal element is combined with the resilient mechanically strong contact member into a mechanically strong flat vibrating unit having a driven bone-engaging contact portion which carries resiliently a driving vibratory mass portion of a mass of the order of two to three grams or somewhat greater up to about ten to twenty grams, the vibrating unit being substantially confined in a small space having an overall thickness of the order of twice or three times the thickness of the crystal element. The vibrating structure is so arranged that when its driven contact portion is held against the bones, it carries resiliently the driving vibratory portion and couples it to the much larger mass of the bones into a vibratory system; the mass of the driving vibratory portion and the stiffness of its resilient junction to the bones being so designed and proportioned that the vibratory system which they form has a resonance frequency which gives a good vibratory response over the principal part of the speech frequency range.

In the vibrating structure utilized for the bone conduction receiver of the invention, a portion of the length of the crystal element and the resilient contact plate united thereto form the resilient junction between the contact surface portion and the vibratory mass portion resiliently carried by the contact portion, the resilience of the mass being substantially distributed over the entire length of the vibrating structure.

The contact portion of the vibratory structure of the bone conduction receivers of the invention

has sufficiently large lateral dimensions and is so arranged relatively to the other elements of the vibratory structure as to maintain it in a stable equilibrium coupling position on the bone under a relatively small external coupling force, making it possible to utilize a universal joint connection for holding the bone conduction receiver coupled to the bone.

A practical bone conduction receiver of the general type described above in connection with Figs. 2 to 7 may be constructed with the following principal dimensions: A vibrating structure formed of a crystal element having a thickness of the order of one-eighth of an inch, a length of the order of one inch, with overall dimensions of the vibrating structure having a thickness of the order of twice the thickness of the crystal element. Efficient and inconspicuously small bone conduction receivers of the type described above may be designed with driving vibratory masses up to about 40 grams or more, and down as low as a driving vibratory mass of the order of 2 grams.

The inventive features involving the arrangement of the cover member extending over the exterior side of the elastically deformable vibratory unit, formed of a crystal element and a strong contact wall member secured thereto, so that at least a portion of the mass of the cover member forms part of the driving mass structure of the bone receiver, do not constitute part of the present invention, but are claimed in the copending application Serial No. 470,463, filed December 29, 1942, by Richard W. Carlisle, and assigned to the assignee of the present application.

The principles of the invention explained in connection with specific exemplifications thereof will suggest to those skilled in the art many other applications and modifications of the same. It is accordingly desired that the appended claims be construed broadly, and that they shall not be limited to the specific details shown and described in connection with exemplifications thereof.

I claim:

1. In a wearable bone conduction hearing aid device, a vibratory unit designed to be coupled to the massive bone body surrounding the inner ears of the user; said vibratory unit comprising a piezo-electric crystal element and a mechanically-strong wall member extending adjacent to one side of said crystal element; said wall member having at least two spaced portions united to two spaced facing portions of said crystal element; said crystal element and said wall member having intermediate elastic elements and being joined into an elastically deformable vibratory structure having at least two driving vibratory portions interconnected through said elastic elements to an intermediate driven bone-coupling portion thereof; said driving vibratory portions being formed of portions of said crystal element and adjacent portions of said wall member; electrode means associated with said crystal element for producing vibrations of said driving vibratory portions relatively to said intermediate bone-coupling portion; a wall portion of said intermediate bone-coupling portion having an outward contact surface arranged to be held coupled against said body so as to resiliently carry said driving portions in a vibratory condition and to operatively couple through said elastic elements the small mass of said vibratory portions with said body into a hearing imparting vibrating system having a resonant frequency which gives a good vibratory response in the speech frequency range.

2. In a wearable bone conduction hearing aid device, a vibratory unit designed to be coupled to the massive bone body surrounding the inner ears of the user; said vibratory unit comprising a piezo-electric crystal element and a mechanically-strong wall member extending adjacent to one side of said crystal element; said wall member having at least two spaced portions united to two spaced facing portions of said crystal element; said crystal element and said wall member having intermediate elastic elements and being joined into an elastically deformable vibratory structure having at least two driving vibratory portions interconnected through said elastic elements to an intermediate driven bone-coupling portion thereof; said driving vibratory portions being formed of portions of said crystal element and adjacent portions of said wall member; electrode means associated with said crystal element for producing vibrations of said driving vibratory portions relatively to said intermediate bone-coupling portion; a wall portion of said intermediate bone-coupling portion being substantially rigid and having an outward contact surface arranged to be held coupled against said body so as to resiliently carry said driving portions in a vibratory condition and to operatively couple through said elastic elements the small mass of said vibratory portions with said body into a hearing imparting vibratory system having a resonant frequency which gives a good vibratory response in the speech frequency range.

3. In a wearable bone conduction hearing aid device, a vibratory unit designed to be coupled to the massive bone body surrounding the inner ears of the user; said vibratory unit comprising a piezo-electric crystal element and a mechanically-strong wall member extending adjacent to one side of said crystal element; said wall member having at least two spaced portions united to two spaced facing portions of said crystal element; said crystal element and said wall member having intermediate elastic elements and being joined into an elastically deformable vibratory structure having at least two driving vibratory portions interconnected through said elastic elements to an intermediate driven bone-coupling portion thereof; said driving vibratory portions being formed of portions of said crystal element and adjacent portions of said wall member; electrode means associated with said crystal element for producing vibrations of said driving vibratory portions relatively to said intermediate bone-coupling portion; a wall portion of said intermediate bone-coupling portion having an outward contact surface arranged to be held coupled against said body so as to resiliently carry said driving portions in a vibratory condition and to operatively couple through said elastic elements the small mass of said vibratory portions with said body into a hearing imparting vibratory system having a resonant frequency which gives a good vibratory response in the speech frequency range; said contact surface forming part of an exposed wall surface of said vibratory unit sufficiently extended and so arranged relatively to said driving vibratory portions as to maintain said vibratory unit in a stable-equilibrium coupling position on the bone body under a relatively small external coupling force

4. In a wearable bone conduction hearing aid device, a vibratory unit designed to be coupled to the massive bone body surrounding the inner

ears of the user; said vibratory unit comprising a piezo-electric crystal element and a mechanically-strong wall member extending adjacent to one side of said crystal element; said wall member having at least two spaced portions united to two spaced facing portions of said crystal element; said crystal element and said wall member having intermediate elastic elements and being joined into an elastically deformable vibratory structure having at least two driving vibratory portions interconnected through said elastic elements to an intermediate driven bone-coupling portion thereof; said driving vibratory portions being formed of portions of said crystal element and adjacent portions of said wall member; electrode means associated with said crystal element for producing vibrations of said driving vibratory portions relatively to said intermediate bone-coupling portion; a wall portion of said intermediate bone-coupling portion having an outward contact surface arranged to be held coupled against said body so as to resiliently carry said driving portions in a vibratory condition and to operatively couple through said elastic elements the small mass of said vibratory portions with said body into a hearing imparting vibratory system having a resonant frequency which gives a good vibratory response in the speech frequency range; said vibratory unit having secured thereto a cover member extending adjacent the side of said crystal element opposite said contact member and having rigid structural elements extending along the space across which said driving vibratory portions vibrate so as to protect them against disturbance by external forces.

5. In a wearable bone conduction hearing aid device, a vibratory unit designed to be coupled to the massive bone body surrounding the inner ears of the user; said vibratory unit comprising a piezo-electric crystal element and a mechanically-strong wall member extending adjacent to one side of said crystal element; said wall member having at least two spaced portions united to two spaced facing portions of said crystal element; said crystal element and said wall member having intermediate elastic elements and being joined into an elastically deformable vibratory structure having at least two driving vibratory portions interconnected through said elastic elements to an intermediate driven bone-coupling portion thereof; said driving vibratory portions being formed of portions of said crystal element and adjacent portions of said wall member; electrode means including electrodes associated with said crystal element for producing vibrations of said driving vibratory portions relatively to said intermediate bone-coupling portion and causing said bone-coupling portion to operate as a nodal portion of said vibratory unit; a wall portion of said intermediate bone-coupling portion having an outward contact surface arranged to be held coupled against said body so as to resiliently carry said driving portions in a vibratory condition and to operatively couple through said elastic elements the small mass of said vibratory portions with said body into a hearing imparting vibratory system having a resonant frequency which gives a good vibratory response in the speech frequency range; said contact surface forming part of an exposed wall surface of said vibratory unit sufficiently extended and so arranged relatively to said driving vibratory portions as to maintain said vibratory unit in a stable-equilibrium coupling position on the bone body under a relatively small external coupling force; said vibratory unit having secured thereto a cover member extending adjacent the side of said crystal element opposite said contact member and having rigid structural elements extending along the space across which said driving vibratory portions vibrate so as to protect them against disturbance by external forces.

6. In a wearable bone conduction hearing aid device, a vibratory unit designed to be coupled to the massive bone body surrounding the inner ears of the user; said vibratory unit comprising a piezo-electric crystal element and a mechanically-strong wall member extending adjacent to one side of said crystal element; said wall member having at least two spaced portions united to two spaced facing portions of said crystal element; said crystal element and said wall member having intermediate elastic elements and being joined into an elastically deformable vibratory structure having at least two driving vibratory portions interconnected through said elastic elements to an intermediate driven bone-coupling portion thereof; said driving vibratory portions being formed of portions of said crystal element and adjacent portions of said wall member; electrode means associated with said crystal element for producing vibrations of said driving vibratory portions relatively to said intermediate bone-coupling portion; a wall portion of said intermediate bone-coupling portion having an outward contact surface arranged to be held coupled against said body so as to resiliently carry said driving portions in a vibratory condition and to operatively couple through said elastic elements the small mass of said vibratory portions with said body into a hearing imparting vibratory system having a resonant frequency which gives a good vibratory response in the speech frequency range; said vibratory unit having secured thereto a cover member extending adjacent the side of said crystal element opposite said contact member and having rigid structural elements extending along the space across which said driving vibratory portions vibrate so as to protect them against disturbance by external forces; said cover member having an intermediate portion clamped to said contact member in the region of its contact surface portion.

7. In a wearable bone conduction hearing aid device, a vibratory unit designed to be coupled to the massave bone body surrounding the inner ears of the user; said vibratory unit comprising a piezo-electric crystal element and a mechanically-strong wall member extending adjacent to one side of said crystal element; said wall member having at least two spaced portions united to two spaced facing portions of said crystal element; said crystal element and said wall member having intermediate elastic elements and being joined into an elastically deformable vibratory structure having at least two driving vibratory portions interconnected through said elastic elements to an intermediate driven bone-coupling portion thereof; said driving vibratory portions being formed of portions of said crystal element and adjacent portions of said wall member; electrode means associated with said crystal element for producing vibrations of said driving vibratory portions relatively to said intermediate bone-coupling portion and causing said bone-coupling portion to operate as a nodal portion of said vibratory unit; a wall portion of said intermediate bone-coupling portion having an outward contact surface arranged to be held coupled against said body so as to resiliently

carry said driving portions in a vibratory condition and to operatively couple through said elastic elements the small mass of said vibratory portions with said body into a hearing imparting vibratory system having a resonant frequency which gives a good vibratory response in the speech frequency range; said contact surface forming part of an exposed wall surface of said vibratory unit sufficiently extended and so arranged relatively to said driving vibratory portions as to maintain said vibratory unit in a stable-equilibrium coupling position on the bone body under a relatively small external coupling force; said vibratory unit having secured thereto a cover member extending adjacent the side of said crystal element opposite said contact member and having rigid structural elements extending along the space across which said driving vibratory portions vibrate so as to protect them against disturbance by external forces; said cover member having an intermediate portion clamped to said contact member in the region of its contact surface portion.

HEIMAN W. KOREN.