April 17, 1962 W. F. KNAUERT 3,030,456

BONE-CONDUCTION ALL-IN-ONE TRANSISTOR AMPLIFIER HEARING AID

Filed Dec. 8, 1958 3 Sheets-Sheet 1

FIG.1

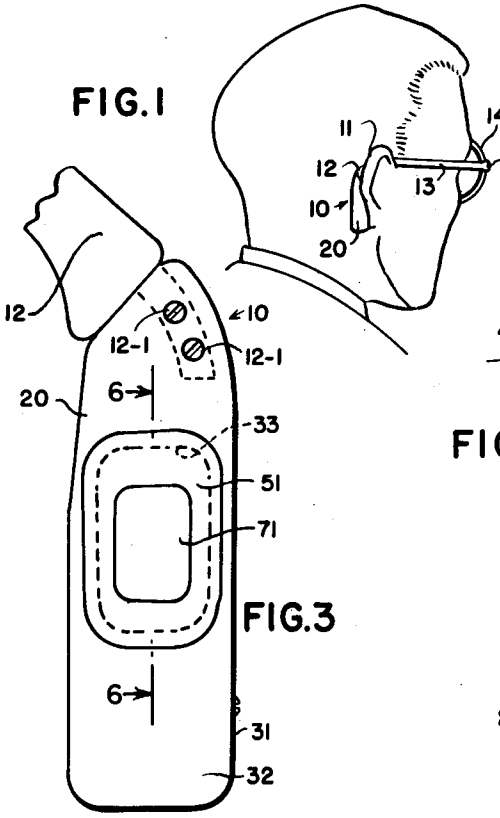


FIG.2

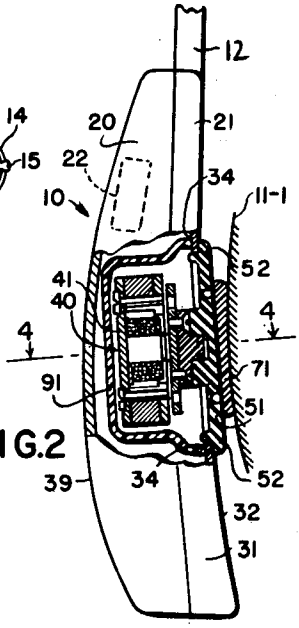


FIG.3

FIG.4

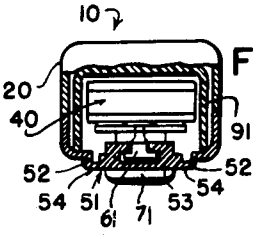
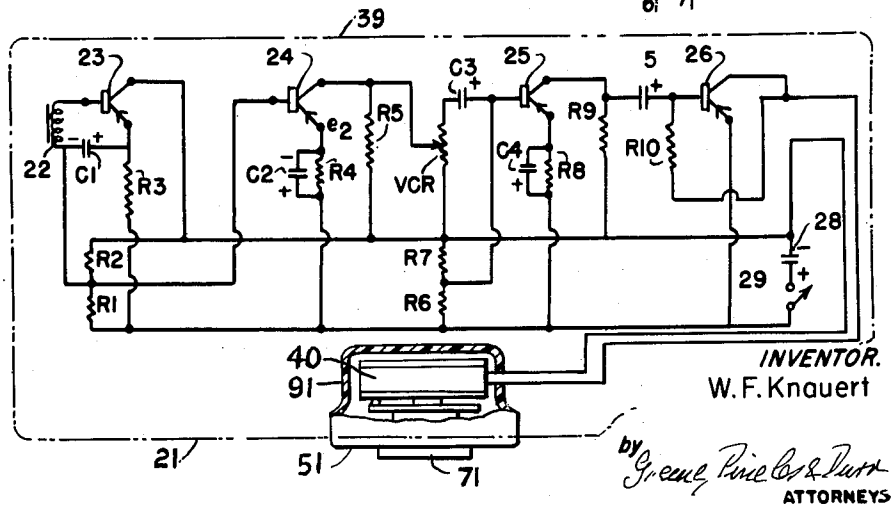


FIG.5



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April 17, 1962 W. F. KNAUERT 3,030,456

BONE-CONDUCTION ALL-IN-ONE TRANSISTOR AMPLIFIER HEARING AID

Filed Dec. 8, 1958 3 Sheets-Sheet 2

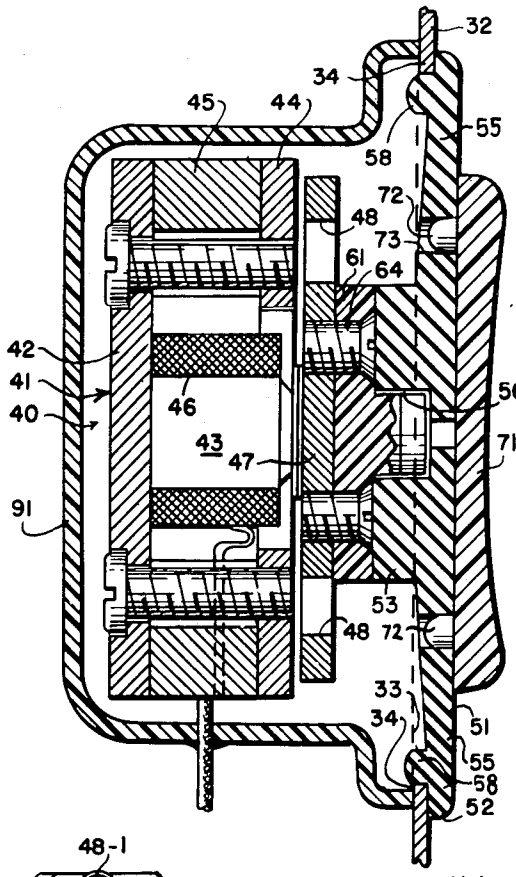


FIG.6

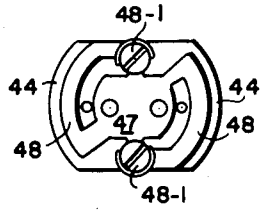


FIG.7

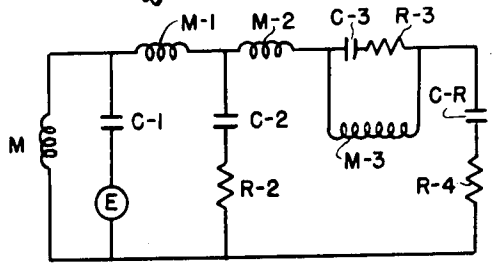


FIG.8

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April 17, 1962 W. F. KNAUERT 3,030,456

BONE-CONDUCTION ALL-IN-ONE TRANSISTOR AMPLIFIER HEARING AID

Filed Dec. 8, 1958 3 Sheets-Sheet 3

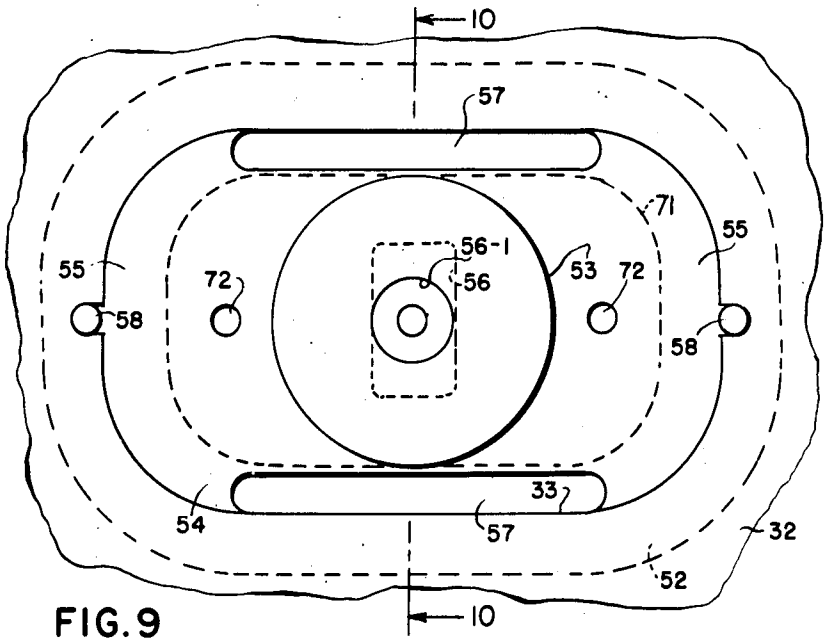


FIG. 9

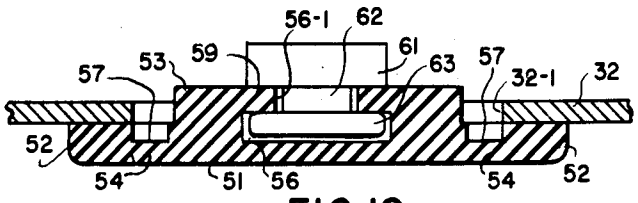


FIG. 10

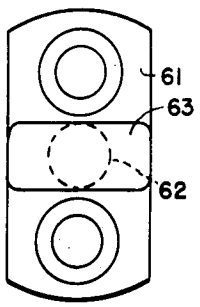


FIG. 11

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United States Patent Office 3,030,456 Patented Apr. 17, 1962

3,030,456

BONE-CONDUCTION ALL-IN-ONE TRANSISTOR AMPLIFIER HEARING AID

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Filed Dec. 8, 1958, Ser. No. 778,992
4 Claims. (Cl. 179—107)

This invention relates to all-in-one bone-conduction transistor hearing aids wherein all their elements including the microphone, the transistor amplifier with its energizing battery cell, together with a bone-conduction receiver, are combined within a casing enclosure into a single miniature-size unit having an over-all volume small enough to be worn inconspicuously behind the ear of the user with the vibration-transmitting bone-contacting wall of the bone-conduction receiver held against a bony part of the head for transmitting thereto audio-frequency vibrations which enable the user to hear the amplified picked-up sound by bone conduction. In practice, the bone receiver of such bone-conduction hearing aid has to be driven by a transistor amplifier operating with a gain of the order of 90 decibels and a power output of several milliwatts, in the case of a spectacle-carried bone receiver. A headband-carried hearing bone receiver may be operated with a higher amplifier output as high as 100 milliwatts. Accordingly, it is essential to suppress feedback of the vibrations and acoustic excitation of the so-driven bone receiver to the microphone, for assuring that the over-all vibration and acoustic feedback from the bone receiver to the microphone is insufficient to set up self-sustained oscillations and whistling.

It is understood that as used in the specification and claims herein, the expression "suppress" is intended to mean attenuation of an undesirable action to a degree sufficient for securing the desired over-all effect.

Among the objects of the invention is an all-in-one hearing aid of the foregoing type wherein feedback of vibrations and acoustic excitation from the bone receiver to the microphone is maintained below a level at which such feedback might set up self-sustained oscillations and whistling. In accordance with a broad phase of the invention, a casing enclosing the bone receiver and forming part of the mechanical structure carrying and housing the microphone and the amplifier with its energizing battery cell of an all-in-one hearing aid, has a casing wall with a casing opening through which the bone-contacting member of the bone receiver is exposed for engagement under pressure with the hearing-inducing bones of the user, with the bone-coupling member and the bone receiver being carried along the casing opening by a resilient looplike vibration barrier which joins the peripheral region of the bone-coupling member to the casing edge region of the casing opening while the looplike vibration barrier suppresses transmission of vibrations from the bone receiver and its bone-coupling member to the casing of the hearing aid and any other associated mechanical structures carrying the microphone and the amplifier elements of the hearing aid.

In accordance with a specific form of the invention, a casing wall—of a tiny casing housing and combining therein all operating elements of a bone-conduction hearing aid, and small enough for inconspicuous wear behind the external ear in the vicinity of the mastoid bone—has a relatively extended resilient and yieldable elastomer wall of vibration-dissipating elastomer material which carries on an intermediate or central elastomer wall section thereof essentially all operating elements of the bone receiver for transmitting through the central elastomer wall section the hearing-inducing inertia reaction vibrations of the internally-carried bone receiver to the hearing-inducing bones of the user's head, while the peripheral

region of the elastomer wall surrounding its central bone-coupling wall section suppresses transmission of the bone-receiver vibrations to the surrounding relatively rigid casing walls of the hearing-aid casing and assures that the over-all vibration and acoustic feedback from the bone receiver to the microphone is below the level that would cause generation of sustained oscillations and whistling. The tiny casing of such all-in-one bone-conduction hearing aid of the invention may be carried behind the user's external ear, either by the rear part or bow of a temple of the user's spectacles, or by a headband, or in general, by any of the supports used for holding the known bone-conduction receivers in vibration-transmitting contact engagement with the mastoid bone of the user.

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 an elevational view of an all-in-one bone-conduction hearing aid of the invention as it is worn on the temple bow of a spectacle frame behind the ear of the user;

FIG. 2 is a side view on an enlarged scale, with a part in cross-section, of the tiny encased all-in-one bone-conduction hearing aid shown in FIG. 1;

FIG. 3 is a view on the same scale of the same encased hearing aid as seen from the bone-contacting side thereof;

FIG. 4 is a partial cross-sectional view of the encased hearing aid along lines **4—4** of FIG. 2;

FIG. 5 is a diagrammatic view, including a circuit diagram of all operative elements of the encased all-in-one bone-conduction hearing aid shown in FIGS. 1–4;

FIG. 6 is a cross-sectional view along lines **6—6** of FIG. 3, showing the bone-receiver part of the hearing-aid casing;

FIG. 7 is a bottom view of the electromagnetic transducer of the bone receiver of FIG. 6, as seen from the downward side of this figure;

FIG. 8 is an analogous electric circuit of constants which represent the operative relationship of the bone-receiver transducer to the elements through which it is joined to the casing of the all-in-one bone-conduction hearing aid on which it is carried;

FIG. 9 is a top view of the elastomer wall on which the bone-receiver transducer is carried together with the bone-receiver junction member and a portion of the surrounding casing wall, as seen from the upper side of FIG. 6;

FIG. 10 is a cross-sectional view of the elastomer wall along line **10—10** of FIG. 9, without the bone-receiver transducer; and

FIG. 11 is a top view of the junction member which joints the bone-receiver transducer unit to the elastomer wall, as seen from the downward side of FIG. 10.

Referring to FIGS. 1–4, the all-in-one bone conduction hearing-aid unit of the invention generally designated **10**, has all of its elements enclosed in a tiny casing **20** the over-all dimensions of which are small enough so that it may be worn unobtrusively behind the external ear **11** of the user's head with the bone-contacting wall of its bone receiver engaging the user's mastoid bone for enabling him to hear by bone conduction. The hearing-aid unit **10** is shown held along the mastoid bone behind the external ear of the user by attaching its upper casing end **21** to the rear end or bow **12** of a temple **13** of spectacle frame **14** of conventional spectacles worn by the user. As indicated in FIG. 3, an end of the temple bow **12** fits into a nest of the upper casing end **21** and is suitably secured thereto, as by two screws so that the temple may press the casing contact wall toward contact

engagement with the bones of the user's head. The temple **13** is connected to the spectacle frame by the usual hinge connection **15**. Each of the two temples of such spectacle frame may carry and hold coupled such all-in-one bone-conduction hearing aids **10** of the invention to the bones on opposite sides of the user's head. Instead of carrying the bone-conduction hearing aid **10** on the rim bow of a spectacle, the upper end of its casing **20** may be attached to the end of a spring headband held on the head of the user, for instance in the way conventional bone receivers are worn and held pressed against the mastoid bone, as described, for instance, in U.S. Patent Re. 21,030. In general, any of the supports used for holding bone receivers in vibration-transmitting contact engagement with the mastoid bone of the user, may be used for holding the all-in-one bone-conduction hearing aid **10** coupled to the mastoid bone behind the external ear of the user.

The tiny casing **20** of the all-in-one bone-conduction hearing aid **10** so worn behind the ear of the user, encloses and combines therein all the operating elements and components of a bone-conduction hearing aid, including a microphone, a multi-stage transistor amplifier with its energizing battery, and a bone receiver which transmits hearing-inducing vibrations to the bones of the user for enabling him to hear by bone conduction. Without thereby in any way limiting the invention thereto, there will now be described in connection with the circuit diagram of FIG. 5, by way of example, all operating elements and components of a bone-conduction hearing aid combined within the tiny casing **20** shown in FIGS. 1–4.

Referring to FIG. 5, the casing **20** encloses and combines therein a microphone **22**, the output of which is impressed on a transistor amplifier having four transistors **23**, **24**, **25**, **26**, which supplies the amplified microphone output to bone receiver **40**. The circuits of all four transistors **23–26** are energized from a single energy source consisting of a tiny battery cell **28** which may be connected to or disconnected from the transistor circuits by switch **29**. The microphone **22** has an electromagnetic sound-energy transducer of the type described in U.S. Patent 2,432,424, and is of miniature size, such as described and claimed in the copending application of W. F. Knauert, Serial No. 774,438, filed November 17, 1958.

The microphone output is impressed on the base and emitter of the transistor **23** of the first amplifier stage. The amplified output of the first amplifier stage is impressed on the base and emitter of transistor **24** of the second amplifier stage. The amplified output of the second amplifier stage is impressed on the base and emitter of transistor **25** of the third amplifier stage. The amplified output of the third amplifier stage is impressed on the base and emitter of transistor **26** of the last or output amplifier stage. The base and emitter of transistors **23**, **24** have applied thereto proper direct-current bias by their shown circuit connections to the voltage-dividing resistances **R1**, **R2**, which are connected between two opposite-polarity battery leads from the opposite terminals of battery cell **28**. The base and emitter of third transistor **25** have applied thereto proper direct-current bias by their shown circuit connections to the voltage-dividing resistances which are similarly connected between the opposite-polarity battery leads. The amplifier circuits of the first transistor **23** include emitter resistance R3 and coupling capacitor C1. The amplifier circuits of the second transistor **24** include emitter resistance R4 which is bypassed by capacitor C2 and collector resistance R5 which is connected to the movable tap of the volume control resistance VCR. The amplifier circuits of the third transistor **25** include emitter resistance R8 which is bypassed by capacitor C4, collector resistance R9, and coupling capacitor C5 through which it is coupled to the next output amplifier stage of transistor **26**. The circuits of the fourth transistor **26** include base resistance **R10** through which proper direct-current bias relations are maintained between its base and emitter.

To enable ready practice of the invention, and without thereby in any way limiting its scope, there are given below, by way of example, data about the various circuit elements of the amplifier shown:

Battery cell of 1.3 volts. Transistors **23, 24** are Raytheon 891, and transistors **25, 26** are Raytheon 892 transistors. Alternatively, all transistors are Philco M–1 transistors.

Resistances:	K ohm
R1	6.8
R2	15.0
R3	1.5
R4	1.5
R5	1.5
R6	10.0
R7	18.0
R8	1.2
R9	1.5
R10	22.0
VCR	20.0

Capacitors:	
C1	4 mfd., 4 v. tantalytic
C2	8 mfd., 2 v. tantalytic
C3	4 mfd., 4 v. tantalytic
C4	1 mfd., 4 v. tantalytic
C5	1 mfd., 4 v. tantalytic

In the form of the invention shown in FIGS. 1–10, all of the above-described elements or components of the complete multi-stage transistor amplifier hearing aid shown diagrammatically in FIG. 5, including the bone receiver **40** described in more detail hereinafter, are housed and combined within the tiny elongated or oblong casing **20** of a size and shape which fits inconspicuously behind the external ear adjacent the mastoid bone of the user. Referring to FIGS. 2–4, the casing **20** consists of a hollow bottom or contact casing section **31** with a casing contact wall **32** and a complementary hollow top or cover casing section **39**, which enclose on all sides the interior casing space. Each of the two casing sections **31, 39** is formed, as by drawing with suitable drawing dies, out of stainless steel stock about .010" thick, so as to give the walls of each hollow casing section a relatively high degree of rigidity and resistance to deformation. The two hollow casing sections **31, 39** are suitably joined to each other along mating edge surfaces or edges **38** of their side walls or rims. This may be done by fastening elements such as screws (not shown) passing through fastening holes of the cover section **39** and engaging fastening elements extending from or secured to wall portions of the contact casing section **31**.

All components of the bone-conduction hearing aid described above in connection with the diagram of FIG. 5, except the bone-conrduction receiver **40**, are suitably supported and mounted in the interior of the casing **20** on chassis frame portions (not shown) which are suitably affixed to the casing **20**. The tiny rectangular microphone **22** may be suitably mounted on the chassis, for instance, in the casing space indicated in FIG. 2, being suitably suspended, for instance by a plurality of Z-shaped suspension members of elastomer sheet material, each having one elastomer end arm secured, as by cement, to the exterior of the microphone **22**, and the opposite elastomer end arm secured to a chassis support thereof. Since the details of the mounting of the hearing-aid components other than the bone-conduction receiver do not form part of the present invention, they need not and will not be described herein in more detail.

The casing contact wall **32** of casing bottom section **31** is arranged to overlie and be pressed against the underlying bones of the head. On an intermediate part of the casing contact wall **32** is carried the bone-conduction receiver **40** in such a way as to suppress transmission vi-

brations and acoustic excitation thereof to the microphone 22 to a degree required for assuring that the over-all vibration and acoustic feedback from the bone receiver 40 to the microphone 22 is insufficient or below the level required for setting up sustained electric oscillations and whistling that would destroy the usefulness of the hearing aid.

An all-in-one bone-conduction hearing aid of the invention of the type described above, may embody a bone-conduction receiver operating with any of the known types of electromechanical transducer structures, such as piezo-electric, or dielectrostrictive transducer structures. The present invention will be explained in connection with a known electromagnetic transducer structure of the type generally used in conventional inertia-reaction bone-conduction receivers.

Referring to FIGS. 6 and 7, the bone-conduction receiver 40 operates with an electromagnetic transducer comprising a floating, resiliently-carried ferromagnetic structure 41 of substantial mass, consisting of a yoke plate 42 having a central core pole 43, a pole plate 44, and permanent magnet core elements 45 held clamped, as by the two screws shown, between the yoke plate 42 and the pole plate 44. The core pole 43 has a pole end passing through an opening in the pole plate 44 and is surrounded by transducer windings 46 so that when energized by audio-frequency currents, corresponding magnetic flux fluctuations will be induced between the pole end of core pole 43 and the surrounding pole plate 44. The magnetic structure 41 is resiliently carried in a floating vibratory condition by magnetic armature 47 at a small gap spacing from the end of core pole 43 (FIG. 6). The armature 47 has two opposite arc-shaped resillient armature junction arms 48 the ends of which are secured, as by clamping screws 48–1, to spaced portions of the pole plate 44 across suitable spacer shims so that the armature 47 resiliently carries at a minute air-gap spacing the overlying magnetic core 41 in a floating vibratory condition and causes it to impart to the armature 47, and therethrough to the bones of the user, hearing-inducing vibrations corresponding to the electric oscillations in transducer windings 46.

In the electromagnetic bone-receiver transducer described above in detail in connection with FIGS. 5 and 6, the relatively large-mass portion of magnetic structure 41 with the transducing windings 46 is resiliently carried in a floating, vibrating condition by the bone-coupled smaller-mass portion of armature 47 for imparting thereto and therethrough to the bones of the user, inertia-reaction vibrations and induce hearing by bone conduction. In conventional bone receivers of the foregoing type, a rigid casing contact wall of a rigid casing enclosing the vibratory transducer structure 40 and held in contact with hearing-inducing bones of the user, is secured, as by screws, to the bone-coupled mass portion of magnetic armature 47.

In an all-in-one bone-conduction transistor-amplifier hearing aid, the bone-coupled vibratory armature mass portion 47 of the bone receiver 40 has to be mounted on the body-contacting wall 32 of the hearing-aid casing 20 in such a way as to transmit the vibratory energy to the hearing-inducing bones of the user, while suppressing vibration and acoustic feedback from the bone-coupled armature 47 and other parts of the bone receiver to the microphone 22 and assure that the over-all vibration and acoustic feedback from the bone receiver 40 to the microphone 22 remains at all times below the level that would cause generation of sustained oscillations and whistling. It should be noted that if transmission of bone-receiver vibrations to the adjacent casing wall 32 are not properly suppressed and sufficient bone-receiver vibrations are imparted to casing wall 32 and the other walls of the casing 20, such casing vibrations will also be picked up by the air inside and outside the casing walls and acoustically transmitted to the microphone 22 which will also pick up vibrations that may be transmitted thereto by the casing walls. As explained in U.S. Knauert Patent 2,832,842, the best generally used bone receivers, when held coupled to the user's bones, operate with a response which has substantial output at frequencies above the range required for adequate speech reception, namely above about 3000 to 4000 c.p.s. For the reasons explained in said Knauert patent, it is highly desirable to suppress or attenuate such high-frequency bone-receiver vibrations, and the Knauert patent discloses a highly effective way of securing the desired suppression of such high-frequency bone-receiver vibrations.

A phase of the present invention provides means for securing smooth cut-off of the undersirable high-frequency bone-receiver vibrations without introducing undesirable peaked response near the upper cut-off frequency. This is accomplished by interposing an elastomer body portion between the internal vibratory bone-receiver system and the user's bones against which the receiver is held.

In accordance with a phase of the invention, this is achieved by making a relatively large section of the casing contact wall 32 of the hearing-aid casing 20 out of a wall body of elastomer material which carries on its intermediate or central region the bone-coupled armature mass portion 47 of the bone-receiver transducer 40, and therethrough the entire mass of bone-receiver transducer 40 in a floating condition, so as to permit efficient transmission of hearing-inducing vibrations from the bone-coupling mass portion 47 to hearing-inducing bones against which it is held, while surrounding elastomer body portions of the elastomer wall body suppress transmission of vibrations and acoustic excitation from the bone receiver 40 to the contact casing wall 32 and other casing portions of the hearing-aid casing 20 to a degree sufficient for maintaining the over-all vibratory and acoustic feedback to the microphone below a prohibitive level at which feedback oscillations and whistling start. In addition, the central elastomer body portion through which the vibrations are transmitted to the user's bones is designed to form an essential part of a mechanical band-pass filter which secures smooth cut-off of the undesirable high-frequency bone-receiver vibrations without introducing undesirable peaked response near the upper cut-off frequency.

The principles of the present invention will now be described by way of example in connection with one form of effective vibration-decoupling connection from the bone-coupled mass portion of a bone receiver to the casing contact wall of an all-in-one bone-conduction hearing aid on which it is carried, as shown in FIGS. 6 and 7, and in detail in FIGS. 9–11. The rigid contact casing wall 32 of the all-in-one hearing aid casing 20 has a relatively large casing opening 33 along the region of the contact wall 32 which overlies the mastoid bone region of the user's head when the all-in-one hearing-aid casing 20 is held coupled thereto behind the external ear of the user. A vibration-decoupling elastomer wall body 51 of resilient, stretchable elastomer material has an area large enough to cover casing opening 33 and to overlap with its peripheral border region 52 the peripheral casing-opening border or edge region 34 adjoining the large casing opening 33. The casing opening 33 of casing contact wall 32 is of oblong shape corresponding to the oblong shape of the bone receiver transducer 40. The casing opening may be large enough so that the transducer 40 may pass through the casing opening 33 into the interior of the hearing-aid casing 20 or be removed therefrom. The vibration-decoupling elastomer wall body 51 is of similar oblong shape, and its border region 52 is secured, as by cement, to the overlapped casing-opening edge region 34.

The large-area elastomer decoupling wall body 51 has at its intermediate or central region (FIGS. 5–10) a thicker bone-coupling elastomer body section 53 shown as a boss projection extending above the level of its surrounding thinner, elastically-yieldable elastomer junction wall sections 54, 55, which separates the bone-coupling

elastomer body section 53 from the border region 52 which is affixed to the casing-opening edge 34. The thin, elastically yieldable elastomer junction wall sections 54, 55 of the elastomer wall body 51 thus constitute a continuous elastomer vibration barrier which surrounds or encircles all sides of the thicker central bone-coupling elastomer body section 53. This continuous elastomer vibration barrier, formed of elastomer wall sections 54, 55, is shaped and designed to have such elastic yieldability and vibration-absorbing or dissipating capacities, as to cause these elastomer wall sectionss 54, 55 to suppress transmission of bone-receiver vibrations from the surrounded bone-coupling elastomer body section 53 to the surrounding casing-opening edge region 34 and other portions of casing 20.

To give the required elastic yieldability to the elongated elastomer wall junction sections 54 extending parallel to the longer borders of the elastomer wall body 51, they are provided with longitudinal depressions 57, thereby reducing their average thickness below the thickness of the other two elastomer wall junction sections 55. To facilitate ready alignment of the elastomer wall body 51 with respect to the casing-opening edge 34 to which they are secured, two peripherally spaced portions of the elastomer wall border 52 are provided with aligning projections 58 shaped to enter into fitting, aligning engagement with aligning openings 35 formed along the edge 34 of the casing opening 33 (FIGS. 6–9).

The central thick bone-coupling elastomer body section 53 of elastomer decoupling wall 51 has affixed to its inwardly-facing side and carries on the interior thereof, the bone-coupling vibratory armature portion 47 together with the floating vibratory transducer mass 41 of bone receiver 40. Any suitable means may be used for securing the bone-coupled armature 47 of the transducer 40 to the interior side of the bone-coupling elastomer body portion 53 of the elastomer decoupling wall 51.

As will be explained hereinafter in connection with the analogue of FIG. 8, this central bone-coupling elastomer body section 53 forms an essential part of the high-frequency cut-off filter mesh or section of the mechanical band-pass filter embodied in the bone receiver of the invention shown in FIGS. 1–10.

Referring to FIGS. 6–11, in the specific form shown, the bone-coupled armature 47 of bone-receiver transducer 40 is affixed to the inward side of the central bone-coupling elastomer body section 53 by a relatively rigid integral junction member 61. Junction member 61 is affixed to the overlying bone-coupling transducer armature 47 and is connected through a neck 62 to an anchor section 63 thereof which is embedded in or secured in clamping, overlapping engagement with interior body portions of the central bone-coupling elastomer body section 53. The junction member 61 engages with and has an area of the same order or slightly smaller than the overlying area of transducer armature 47, and they are secured to each other along flat interfitting surfaces. The upwardly-facing surface of junction member 61 is shown held clamped and affixed to the overlying transducer armature 47 by two flat-head screws 64, the flat heads of which are sunk in suitable tapered openings of junction member 61 (FIG. 6) so that they do not project above the surrounding surface of junction member 61. The anchor section 63 of junction member 61 has substantially the same lateral dimensions as the overlying junction member 61, and their neck 62 has the same width as the smaller lateral dimension of junction member 61 and its anchor section 63. The downwardly-facing surface of junction member 61 as seen in FIG. 6, is shaped to fit and engage with its entire area, the upwardly-facing end surface of the central elastomer coupling body section 53 to which it is secured by its anchor section 63.

The anchor section 63 of junction member 61 is arranged so as to clampingly enter a junction compartment 56 of central bone-coupling elastomer body section 53 through a narrow neck compartment 56–1 thereof and clampingly engage the overlying elastomer compartment wall portions 55. The elastomer-body junction compartment 56 and neck compartment 56–1 are so shaped and dimensioned as to enable elastic deformation of the elastomer compartment wall portions 55 when anchor section 63 of rigid junction member 61 is forced through narrower neck compartment 56–1 into the junction compartment 56 of central bone-coupling elastomer body section 53 for overlapping clamping engagement with the inner surfaces of its elastomer wall portions 55. After junction member 61 is secured to the bone-receiver 40, as by screw connections to its armature 47, the junction anchor section may be forced into the elastomer body junction compartment 56 as follows:

One of the laterally projecting ends of the junction-member anchor section 63 is inserted into the neck opening 56–1 of the central bone-coupling elastomer body section 53, whereupon the adjoining elastomer-compartment wall portions 55 are elastically flexed by anchor section 63 until the entire anchor section 63 is forced through the narrow neck opening 56–1 into the junction compartment 56 of the central bone-coupling elastomer body section 53 directly behind the elastomer-compartment wall portions 55. The elastomer-compartment wall portions 55 have a thickness somewhat greater than the height of the junction neck 62 of junction member 61 for causing the anchor section 63 to maintain the downwardly-facing surface of junction member 61 clamped against the facing end surfaces of central bone-coupling elastomer body portion 53 and its compartment wall portions 55. Before forcing the wider junction-member anchor section 63 into elastomer-body junction compartment 56, suitable cement is applied to the interior surfaces of the junction compartment 56 which are engaged by the junction member 61, so that after the junction-member anchoring section 63 is forced into the junction compartment 56, the anchoring section 63 with its neck 62 as well as the overlying downwardly-facing surface of coupling member 61, as seen in FIG. 10, will be united to the adjacent surface portions of central bone-coupling elastomer body section 53. Although it may be formed out of metal, good results are obtained with a junction member 61 formed of a suitable resin such as nylon. Any of the known adhesives suitable for joining elastomer and resin bodies to each other, may be used, as a cement for joining the junction member 61 to the bone-coupling elastomer body section 53. Good results are obtained with the commercially available thermoplastic cement supplied by B. F. Goodrich & Company under the name "Vulcalock G."

To the exterior surface of the elastomer wall body 51, which underlies the central region of the bone-receiver 40, is secured, as by cement, a relatively rigid or hard contact wall 71 through which the hearing-inducing vibrations are transmitted from transducer 40 to the user's hearing inducing bones. The hard coupling wall 71 may be of the oblong shape shown, and is secured to the overlying surface of the central region 53 of elastomer wall body 51 by cement. Any of the known cements may be used for this purpose. A very strong joint is obtained by the use of cement known as "Eastman 910" adhesive. To simplify proper alignment of the coupling wall 71, is has two widely spaced aligning projections or pins 72 shaped to fit and engage two correspondingly aligned openings 73 in the elastomer body wall 51.

The vibratory motion of the floating transducer structure 41 and the other parts of the bone-receiver transducer 40, will be picked up by the air in the interior of the hearing-aid casing and be acoustically transmitted to the microphone. To suppress such acoustic transmission from the transducer 40 through the air in the hearing-aid casing to the microphone 22 housed therein, the transducer 40 is enclosed on its interior side with a rigid inner hollow casing 91 for providing an acoustic barrier between the casing space in which the bone-receiver transducer 40 op-

erates and the surrounding interior space of the all-in-one hearing-aid casing **20**. Such rigid inner casing **91** is desirably made of metal. However, it may be made of resin. The acoustic-coupling-suppressing inner casing **91** is secured, as by cement, along its downwardly-facing edge, as seen in FIG. 6, to the inward surface of the casing opening edge region **34** to complete the acoustic seal separating the bone receiver space from the other space in the hearing-aid casing **20**.

The operative relationship of the cooperating elements of the vibration-suppressing elastomer barrier loop **54, 55**, its band-pass filter section **53**, the bone-receiver **40** and the casing **20**, may be represented by the electric circuit analogue of FIG. 8. In the circuit of FIG. 8,

M is the effective mass of the floating large bone-receiver structure **41**.

E is the driving force between the large floating bone receiver mass **41** and armature **47**.

C–1 is the effective compliance of the spring element **38** of the armature spring **47** through which it is connected to the large floating mass **41**.

M–1 is the effective mass of the armature **47**.

C–2 and R–2 are the compliance and the mechanical resistance of the central elastomer filter body section **53**.

M–2 is the effective mass of the bone receiver contact member **71**.

M–3 is the effective mass of the casing **20** with its casing contact wall **32**.

C–3 and R–3 are the compliance and the mechanical resistance of the looplike elastomer barrier section **54, 55** separating the bone-coupling central filter elastomer body section **53** from the casing edge.

C–4 and R–4 are the compliance and the resistance of the mastoid bone or the terminal impedance of the bone receiver.

In the electric filter-circuit analogue of FIG. 8, the inductance M–2 (the effective mass of contact wall **71**) of the third filter mesh, and the shunting impedances C–2 and R–2 (the compliance and mechanical resistance of the central elastomer body section **53**), determine the high-frequency cut-off with which the bone-receiver transducer operates. By designing the mass of contact wall **71** and the compliance of the elastomer body section **53** so that when held coupled to the bones of the user they vibrate with their own resonant frequency in the range between 2000 to 6000 c.p.s., relatively to the other elements of the system shown, the bone-receiver transducer **40** will operate essentially as a mechanical band-pass filter having an attenuated response which rolls off smoothly above such resonant frequency. In practice, good results are obtained by designing the central elastomer body section **53** so that when the bone-receiver contact wall **71** is held against the user's body, the central elastomer body section **53** will resonate with the bone-contacting wall **71** at a resonant frequency of about 4000 c.p.s., and assure efficient operation of the bone receiver over a frequency range slightly beyond this high-frequency resonance with the response attenuating and rolling off smoothly above 4000 c.p.s.

As seen in the electric filter analogue circuit of FIG. 8, the mass of the hearing-aid casing **20** with its casing wall **32** (which is represented by M–3 of the last mesh) is shunted by the looplike elastomer wall barrier section **54, 55** (represented by shunting circuit elements C–3, R–3) through which the bone-coupled transducer is connected to and is carried by the casing. In accordance with the invention, the looplike elastomer body section **54, 55** (circuit elements C–3 and R–3 of FIG. 8) is so designed and proportioned as to cause the vibrations which are transmitted from source E to the user's body (represented by C–4, R–4) to bypass the casing **20** (or M–3 in FIG. 8) of the all-in-one hearing aid, thereby suppressing transmission of bone-receiver vibrations to the casing **20**. In other words, the thin, looplike elastomer barrier section **54, 55** (C–3 and R–3 of FIG. 8) form a vibration shunt for the hearing-aid casing **20** (M–3 of FIG. 8), and this vibration shunt C–3, R–3, may be readily designed with a sufficiently great compliance as to shunt or bypass the vibrations around the hearing-aid casing M–3 and to suppress the transmission of the bone-transducer vibrations to the casing **20** to a degree sufficient to assure that the over-all vibration and acoustic feedback from the bone-receiver transducer to the microphone is below a level at which sustained oscillations and whistling are set up.

In the drawings of the present application, the bone-receiver transducer structure **40** shown in FIGS. 2–7 is of oblong shape, and the major dimension of this transducer structure **40** extends in a direction parallel to the major dimension of the elongated casing **20** of the all-in-one hearing aid **10**. However, applicant's assignee is about to place on the market a bone receiver having only half the mass and volume of its heretofore manufactured bone receivers. Such smaller bone receiver may be mounted in an all-in-one hearing aid casing **20** of the type shown in FIGS. 1–10, so that the major dimension of the transducer structure **40** fits within and extends transversely to the major dimension of the elongated casing **20** of the all-in-one hearing aid shown.

Instead of providing the casing wall **32** of the all-in-one hearing aid **10** with an oblong casing opening **33** along which the bone-receiver transducer is carried, the casing opening **33** may be of circular or other shape and arranged so that the bone-receiver transducer structure **40** is carried along it by a looplike elastomer barrier section corresponding to the circuit elements C–2, R–2, of FIG. 8, and operating in the manner described above.

Instead of using an elastomer vibration-barrier loop, such as elastomer barrier loop **54, 55** described above, for suppressing vibration feedback from the bone receiver **40** to the hearing-aid casing structure **20**, the vibration barrier loop may be made of any elastic material, such as plastic or metal material. In such case, the resistance R–3 of such vibration barrier loop (FIG. 8) has a negligible value in comparison with reactances of the corresponding metallic or like hard spring member represented by C–3 in FIG. 8. However, elastomer bodies have a lower modulus of elasticity than hard bodies of metal or hard plastic material. The lower modulus of elasticity of elastomer bodies makes it possible to provide an elastomer barrier loop, such as loop **54, 55** (FIGS. 2–10) with substantially greater energy-storing capacity for providing the compliance required to secure the desired effect with an all-in-one hearing aid of the same over-all dimensions.

The elastomer body portions of the central elastomer body section **53** which separate the armature **47** from the rigid bone-contacting member **71**, form parts of a mechanical bandpass filter, represented by C–2 and R–2 in FIG. 8, and they are designed to cut off or attenuate high-frequency vibrations transmitted to the skull above the range required for intelligible reproduction of speech, such as above 3,000 to 5,000 c.p.s., a feature of great practical importance in a bone-conduction hearing aid. By using elastomer body portions such as body section **53**, instead of the spring metal of Hawley Patent 2,202,906, or hard plastic wall material of Knauert Patent 2,832,842, for the portion of the mechanical band-pass filter represented by C–2 and R–2 in FIG. 8, this spring element of the band-pass filter may be designed with materially greater energy-storing capacity for securing the desired resonant frequency with the associated vibrating mass M–2 of the system (FIG. 8), within the same over-all dimensions of their combined structures. In addition, by using an elastomer body portion, such as body section **53**, for band-pass filter element C–2, the desired smooth cut-off of undesirable high frequencies is secured without introducing undesirable peaked response in the frequency range corresponding to the resonant frequency of the filter mesh elements represented by M–2, C–2 and R–2 in FIG. 8.

Without in any way limiting the scope of the invention, but only in order to enable more ready practice thereof,

there are given below, the principal data of one form of an all-in-one bone-conduction hearing aid exemplifying the invention described above, and having a bone receiver 40 extending with its major dimension transversely to the major dimension of casing 20 shown in FIGS. 1–11:

Total mass of the all-in-one bone-conduction hearing aid without the bone receiver, was 15 grams.

Casing 20 with maximum width at center of $2\frac{1}{32}$", maximum height of ½", and total length of $2\frac{3}{8}$".

Casing opening in casing wall 32 was ¾" wide along major axis and $\frac{7}{16}$" wide transversely thereto.

The resiliently-carried bone-receiver mass 41 of 7 grams, and armature mass of .4 gram.

Elastomer wall 51, .900" in length and .610" wide. Its central thick elastomer body section 53 was .180" in diameter, its total thickness was .105", and its elastic stiffness was 20×10^6 dynes/cm. (centimeter).

Thinner elastomer loop wall portions 54, 55 were of .055" thickness, with their regions along longitudinal depressions 57 being .030" thick and .450" long. The stiffness of elastomer loop wall portions 54, 55 was about 1×10^6 dynes/cm., and may be as high as 20×10^6 dynes/cm.

The elastomer wall body 51 consisted of neoprene.

Contact wall 71, of .2 gram mass. Stiffness of skin at mastoid bone is on the average of 100×10^6 dynes/cm.

Various other modifications may be made in the arrangement of the invention for assuring the desired suppression of the over-all feedback of mechanical vibrations from the bone receiver to the microphone of an all-in-one hearing-aid casing or mounting structure on which they are mounted or carried. For instance, the bone-contacing wall such as contact wall 71 may be omitted, and the central elastomer body section 53 may be held pressed with its exterior surface against the hearing-inducing bones of the user, for transmitting thereto the hearing-inducing vibrations. To secure the desired band-pass filter high-frequency cut-off above a predetermined high-frequency, such as 4000 c.p.s. mass elements, for instance powder particles of a heavy metal, such as tungsten or molybdenum, may be arranged to be dispersed in the bone-coupled central elastomer body portion 53 so as to provide the mass element M–2 of the filter mesh which resonates with the compliance C–2 of the central elastomer section 53 (FIG. 8) at the desired frequency (4000 c.p.s.) above which the response of the receiver is attenuated or cut off, in the manner explained above. Alternatively, the thickness of central elastomer body portion 53 may be made sufficiently large so as to embody therein the required mass M–2.

The microphone 22 has a sound-pervious wall portion or passage (not shown) through which propagated sound will reach and excite it or its vibratory diaphragm for causing it to generate corresponding electric signals. The sound passage of the microphone is suitably joined as by an elastomer duct to a wall opening (not shown) of the casing 20, so that propagated sound will be transmitted to the microphone through the casing opening and cause it to generate corresponding electric signals, as described, for instance, in the co-pending Knauert application Serial No. 774,438, filed November 17, 1958.

The present application is limited to the phase of the invention involving a relatively rigid junction member, such as junction member 61, which is secured to the bone-coupled portion of the internal vibratory bone-receiver transducer structure and having an integral rigid anchor embedded and secured within an elastomer body junction member through which it is joined to the body-contacting wall structure whereby the bone-receiver transducer is coupled to the body of the user for inducing hearing by bone conduction and the like. Such rigid transducer-carrying junction member having a rigid anchor portion embedded and secured within the elastomer junction body of such bone-receiver high-frequency attenuating band-pass filter section, greatly simplifies accurate assembly of the components of such bone receiver and assures uniform operating characteristics of the production run of such bone receivers. Such rigid transducer-carrying junction members having a rigid anchor portion embedded and secured within the elastomer junction body of such transducer filter section, may also be used for joining the bone-coupled part of the internal electromechanical bone-receiver transducer structure to its enclosing rigid bone-contacting bone-receiver casing, for instance of the type described in connection with FIGS. 14–16 of the co-pending application of H. A. Pearson filed concurrently herewith S.N. 278,991, the disclosure of which is hereby made part hereof.

Other features of the invention disclosed herein constitute the subject-matter claimed in the co-pending application of H. A. Pearson, Serial No. 778,991, filed concurrently herewith.

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 an inertia-reaction bone-receiver hearing aid, the combination of a support element comprising a rigid casing having bone contacting means, an electromechanical vibratory sound receiver enclosed within said casing, a mounting element of elastomer material for said receiver secured to and carried by said casing, said received having an armature secured to said mounting element and fully supporting said receiver thereby, said mounting element constituting the sole means of transmission of sound from said armature to said bone contacting means, an integral junction member constituting the sole connection between said armature and said mounting element, said junction member consisting of harder material than said mounting element, said junction member having an inner junction section secured to said armature an opposite outer anchor section and an intermediate neck section narrower than said anchor junction section, said mounting element having a central body section surrounding and clamping therein said neck section and said anchor section, the resonant frequency of the system which comprises said support element and said mounting element being within the range of 2,000–6,000 cycles per second, and said system constituting in conjunction with said receiver a band-pass filter operative to attentuate frequencies above said resonant frequency in bone coupled condition.

2. In an inertia-reaction bone-receiver hearing aid, a casing with a casing opening and having an elastomer wall of resilient elastomer material secured to said casing along said opening, said elastomer wall carrying bone contacting means, electromechanical vibratory receiver within said casing carried by said elastomer wall and having an armature coupled thereto, said elastomer wall constituting the sole support for said receiver and for said bone contacting means and also constituting the sole path of vibration transmission from said receiver to said bone contacting means, an integral junction member constituting the sole connection between said armature and said elastomer wall, said junction member consisting of harder material than said elastomer wall, said junction member having an inner junction section secured to said armature an opposite outer anchor section and an intermediate neck section narrower than said anchor junction section, said elastomer wall having a central body section surrounding and clamping therein said neck section and said anchor section, the system comprising said casing and said bone contacting means having a resonant frequency of from 2,000 to 6,000 cycles per second and constituting a band-pass filter in conjunction

with said receiver to cut off frequencies above said resonant frequency in bone couple condition.

3. In an inertia-reaction bone-receiver hearing aid as claimed in claim 2, said elastomer wall constituting a continuous elastomer structure forming an acoustic seal along said casing opening.

4. In an inertia-reaction bone-receiver hearing aid as claimed in claim 3, said casing also carrying therein a microphone for picking up sound transmitted in the exterior space outside said casing, a battery cell, and transistor-amplifier means electrically connected to said cell between said microphone and said receiver for causing said receiver to transmit to said contact means bone-conduction vibrations corresponding to picked up microphone signals amplified by said amplifier means.

References Cited in the file of this patent

UNITED STATES PATENTS

2,832,842	Knauert	Apr. 29, 1958
2,858,376	Lewis	Oct. 28, 1958
2,874,230	Carlson	Feb. 17, 1959

FOREIGN PATENTS

761,169	Great Britain	Nov. 14, 1956