April 20, 1937. H. LIEBER 2,077,425

BONE CONDUCTION HEARING AID

Original Filed Dec. 24, 1932 2 Sheets-Sheet 1

Fig. 1

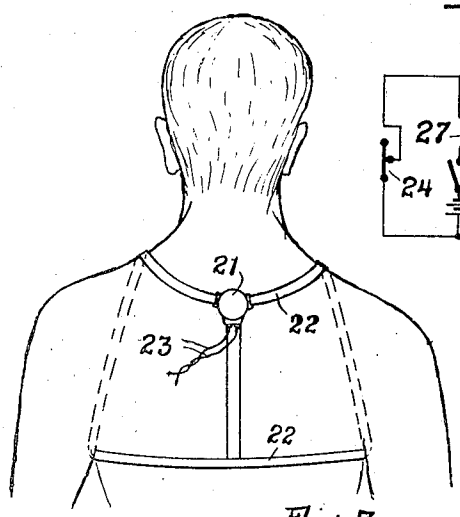


Fig. 2

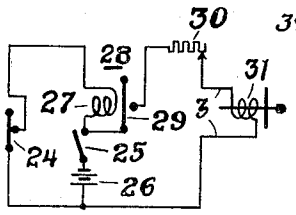


Fig. 5

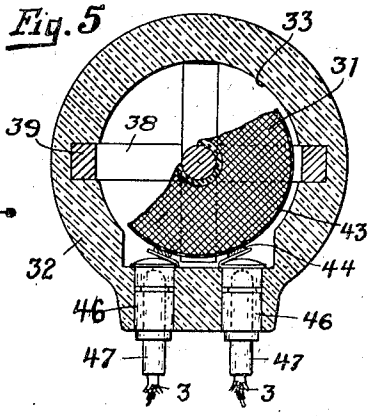


Fig. 6

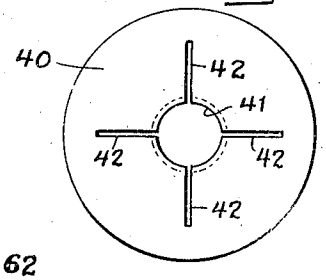


Fig. 3

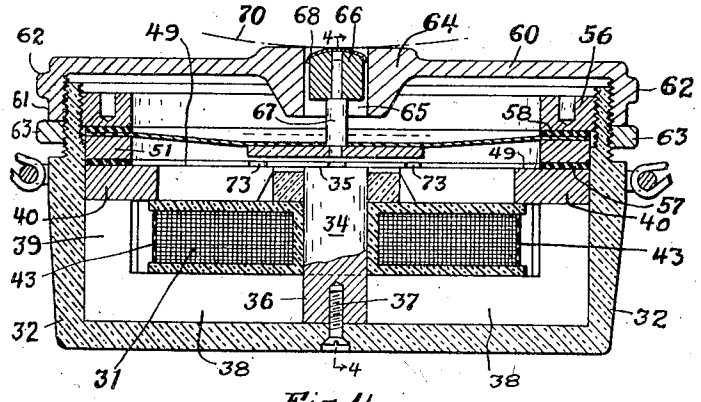


Fig. 7

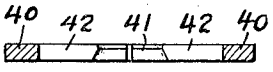


Fig. 8

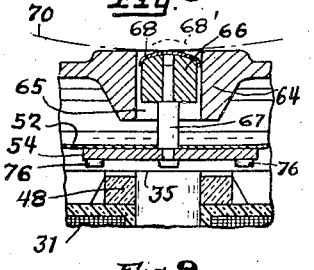


Fig. 4

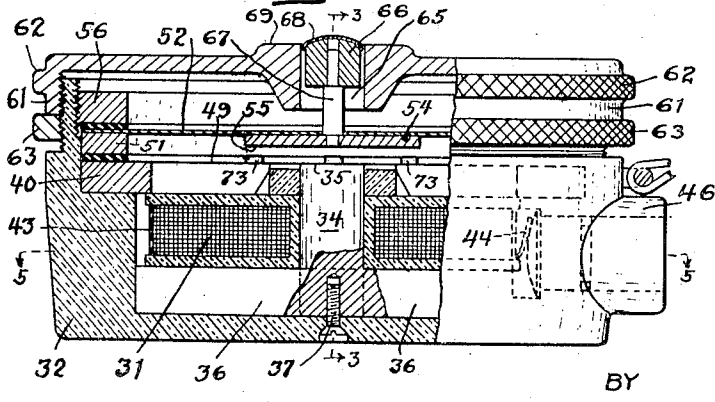
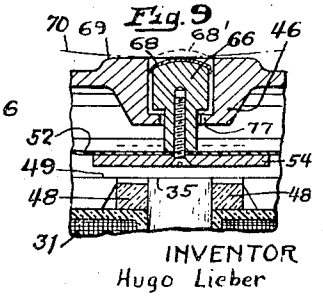


Fig. 9



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BONE CONDUCTION HEARING AID

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Fig. 11

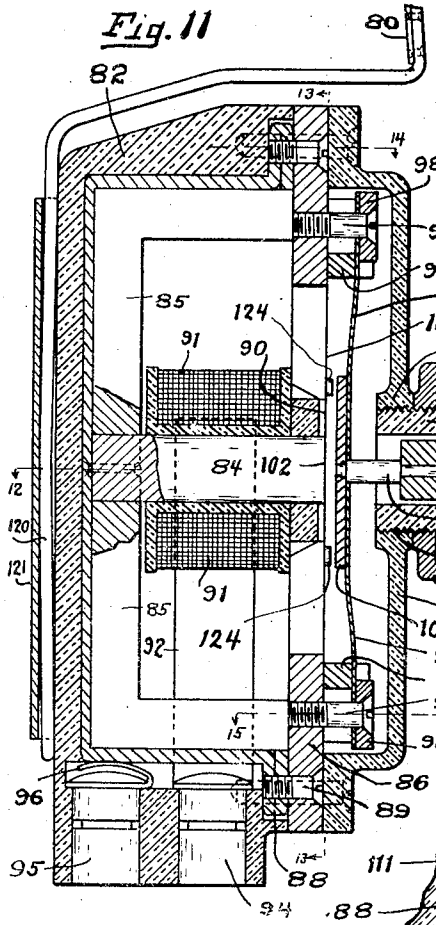


Fig. 10

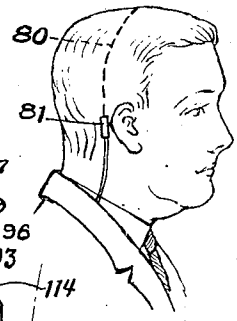


Fig. 13

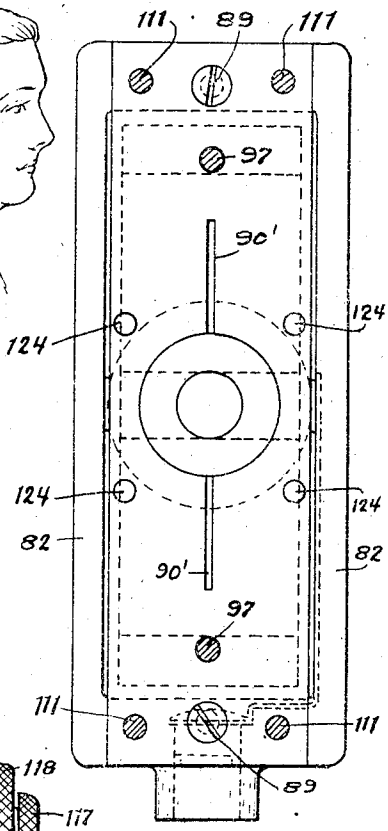


Fig. 14

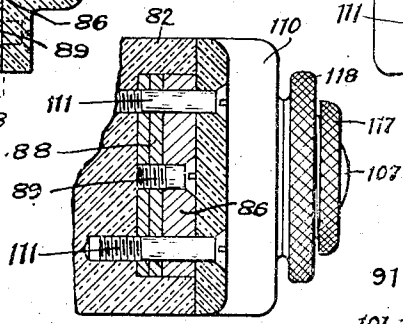


Fig. 16

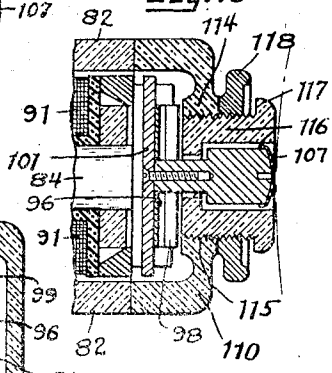


Fig. 12

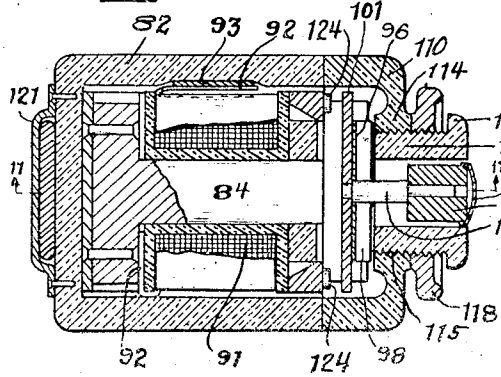
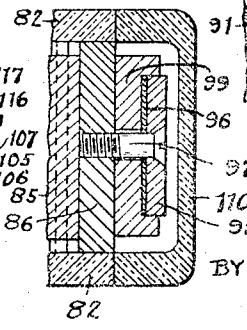


Fig. 15



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REISSUED

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UNITED STATES PATENT OFFICE

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BONE CONDUCTION HEARING-AID

Hugo Lieber, New York, N. Y., assignor, by mesne assignments, to Lieber Patents Corporation, New York, N. Y., a corporation of New York

Application December 24, 1932, Serial No. 648,733
Renewed February 28, 1934

1 Claim. (Cl. 179—107)

This invention relates to bone conduction hearing-aids, and it has among its objects an improved bone conduction receiver of small size and light weight suitable for inconspicuous wear by the user and able to impart to the bone structure of a hard of hearing person the vibratory energy required for inducing hearing in his auditory nerve center.

The foregoing and other objects of the invention will be best understood from the following description, reference being made to the accompanying drawings, in which

Fig. 1 is a view of the vibrator element illustrating how a bone conduction receiver of the invention may be held against the bone structure of the upper portion of the spinal column of a person hard-of-hearing;

Fig. 2 is a circuit diagram of a hearing-aid device;

Fig. 3 is a vertical sectional view through the bone conduction receiver along line 3—3 of Fig. 4;

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

Fig. 5 is a horizontal sectional view through the receiver along line 5—5 of Fig. 4;

Fig. 6 is a top view and Fig. 7 is a cross sectional view of the pole plate of the receiver;

Figs. 8 and 9 are vertical sectional views similar to Fig. 3 of the center portion of a receiver embodying modifications of the invention;

Fig. 10 is a view of a modified form of a bone conduction receiver of the invention as carried on the head of a person;

Fig. 11 is a vertical sectional view through the receiver of Fig. 10 along line 11—11 of Fig. 12;

Fig. 12 is a vertical sectional view along line 12—12 of Fig. 11;

Fig. 13 is an elevational view of the vibrator casing of Fig. 11, with the cover and the vibrating diaphragm removed, along line 13—13 of Fig. 11;

Fig. 14 is a transverse sectional detail view along line 14—14 of Fig. 11;

Fig. 15 is a transverse sectional detail view along line 15—15 of Fig. 11; and

Fig. 16 is a view similar to Fig. 15 of a modified construction.

Although it has been known for many years that a large percentage of persons with impaired hearing have satisfactory interior hearing organs and that they are able to hear well by bone conduction, prior bone conduction receivers proved impractical because they were all large and cumbersome and could not be made small enough for inconspicuous wear by the user.

The present invention provides an electromagnetic bone conduction receiver of small size capable of imparting to the bone structure of the user an amount of vibratory energy required to induce satisfactory hearing, and yet small and light enough to permit its inconspicuous wear on the person of the user.

Fig. 1 illustrates a hard-of-hearing person having a bone conduction receiver 21 of the invention held pressed against a spinal column bone by means of a light harness of flexible straps 22, the receiver being connected through a flexible double conductor cord 23 with the associated elements, in accordance with the diagram of Fig. 2. The complete hearing-aid comprises a transmitter microphone 24 connected through a cutout switch 25 in series with a battery 26 and actuating coil 27 of a microphone amplifier 28, the microphone 29 of which is connected through switch 25 in series with battery 26 and rheostat 30 to the actuating coil 31 of the bone conduction receiver 21 as in similar air conduction hearing-aids.

The bone conduction receiver 21 is shown in detail in Figs. 3 to 7 and comprises a casing 32 within which is mounted an electromagnetic vibrator core structure comprising a central core 34 surrounded by the actuating coil 31 and two L-shaped permanent magnets 38 so as to produce with the pole plate 40, shown in detail in Figs. 6 and 7, a flux in the annular gap between the core and the pole plate.

Mounted above the pole plate within the casing opening is a diaphragm unit 51 comprising a circular resilient sheet-metal diaphragm 52 held radially tensioned by a tension ring 53. The tension ring may be, for instance, made from a split ring of larger diameter compressed to the diameter of the diaphragm and soldered to the edge thereof so that under the action of the forces tending to restore the ring to its original position, a uniform radial tension is applied to the diaphragm.

To the underside of the diaphragm is secured, as by soldering, a flat circular armature 54 of soft iron. The lower surface 55 of the armature 54 is parallel to the pole faces of the central core member 34 and the pole plate 40 and is spaced therefrom by a small gap 56 to provide a path for the permanent flux of the magnets 38 and of the induced flux of coil 31. The diaphragm unit it held firmly in place within the casing by means of a locking ring 56 which is screwed in within

the threaded upper end of the interior casing wall, thin washers 57 serving to properly space the diaphragm unit with respect to the pole faces 35 and 49.

The top of the casing is closed by a cover 60 mounted on an external threaded portion of the casing, and a lock nut ring 63 serves to lock the cover in the desired operating position. The central portion of the cover 60 has a central cylindrical opening 65 for guiding a contact button 66 mounted on a rod 67 extending from the center of the armature 54. The contact button 66 may be mounted in place before inserting the cover by placing it with its central hole over the upper projection of the rod 67 and soldering the two together at the top end, a thin cap 68, of a non-oxidizing material, for instance, gold, being soldered over the top of the junction to form the exterior contact surface of the button 66.

The outer side of the central enlargement 64 of the cover 60 forms a supporting surface 69 around the contact button 66. When the vibrator is in released condition, the outer surface 68 of the contact button projects slightly above the supporting surface 69 of the casing cover, as shown in Fig. 4.

If the bone conduction vibrator is in released condition, that is, not held pressed with the contact button 66 against the bone structure to which vibrations are to be imparted, and the vibrator is connected to the operating circuit as shown in Fig. 2, only a permanent flux is induced in the gaps 56 between the pole faces of the magnet core and the opposite armature face, the flux passing between the inner pole face 35 through the short gap to the armature 54 and then radially through the armature to the outer periphery thereof, and therefrom back through the gap to the outer pole face 49 of the pole plate 40 and therethrough to the opposite poles of the L-shaped magnets, a part of the flux being also induced by the steady current flowing through the coil 31 from the battery 26. This flux will tend to pull the armature 54 towards the pole faces underneath, but the diaphragm 52 is made sufficiently stiff to oppose this magnetic pull and to keep it in the position where the contact button 66 projects above the supporting surface 69, as shown in Fig. 4. On pressing the vibrator against the body, the contact surface 68 is pressed inwardly into the opening 65 of the cover until the outer contact surface 68 of the button lies flush with the supporting surface 69, as shown in Fig. 3, the body portion being indicated by line 70. This brings the armature nearer to the pole pieces, decreasing the air gap.

If sound waves impinge upon the transmitter microphone 24, producing oscillatory currents in the circuit of coil 31, corresponding oscillatory fluxes are induced in the magnet core and these fluxes are superimposed on the permanent flux and cause it to increase and decrease in accordance with the current oscillations. The resulting flux fluctuations vary the attraction exercised on the armature 54 and cause the diaphragm 52 with the elements carried thereby to vibrate in accordance with the flux oscillations. The vibratory action of the diaphragm is imparted through rod 67 to the contact button 66 and causes the latter to vibrate. These mechanical vibrations of the contact button 66 conform to the sound oscillations impinging upon the transmitting microphone 24 and by imparting these mechanical vibrations to the hearing-inducing bone structure of a person, corresponding sounds are induced in the nerve center of the person.

The amount of vibratory power that can be transmitted by a vibrator of this type to the bone structure depends on the area of the pole face of the gap and on the gap length. The larger the active area of the gap and the smaller the length of the gap, the more mechanical power can be transmitted by the vibrator. If the device is to be small and inconspicuous, the pole area must naturally be kept small. The only way then open to make such vibrator develop a substantial amount of undistorted mechanical power is to decrease the gap between the pole faces and the opposite armature surface. This brings, however, about serious difficulties which have prevented in the past the construction of small size inconspicuous vibrators for bone conduction hearing-aids.

In a magnet system with a movable diaphragm disposed close to the pole face, the magnetic flux between the opposite surfaces exercises on these surfaces a very strong attracting force and tries to bring the diaphragm into contact with the pole faces. This action is particularly strong during the operation of the device when the coil is energized and increases the magnetic force, and especially so when current pulsations materially increase the flux. If under such conditions, the gap between the armature and the pole faces is very small, there will be reached a point at which the attractive force of the magnet will pull down the armature into contact with it, rendering the vibrator inoperative. There exists thus a freezing zone in the immediate neighborhood of the pole faces from which the armature must be positively kept out in order to prevent inoperativeness of the vibrator unit. The fact that in pressing the contact button 66 against the bone structure in devices, as shown in Figs. 3 and 4, the gap between the armature and the pole faces is decreased, greatly increases these difficulties, and has been in the past a great obstacle in making small practical bone conduction receivers. In trying to overcome these difficulties in the past, constructions having relatively long operating gaps had to be used. Since the use of long gaps requires large vibrating structures for transmitting the vibratory power, the whole vibrator unit had to be made large, thus becoming bulky and unsuitable for a portable inconspicuous hearing-aid as required in practice.

By the present invention I provide a gap smaller than thought possible in practical devices in the past, and yet avoid to a large extent the difficulties due to freezing. The diaphragm unit is so constructed and mounted that with the actuating coil 11 energized, the armature will be held in a position at which there is a substantial gap between the core pole faces 49 and 35 and the armature face so that the magnetic flux in the gap will under no condition reach a value causing the armature to be pulled into contact with the pole face. A vibrator employing such large gap during operation would, however, have to be too large in size in order to develop power for imparting to the bone structure sufficient vibration to induce audible sounds in the auditory never center.

In accordance with the invention, I provide a much smaller normal operating gap by arranging the contact button 66 to project above the surrounding supporting surface 69 of the casing when in released position as shown in Fig. 4, and to be pushed into the casing, when it is pressed with the button surface 68 against the bone

structure, till it reaches a position where the outer contact surface of the button is substantially flush with the adjacent supporting surface of the casing. This inward motion of the button is accompanied by a corresponding motion of the diaphragm till the armature reaches a predetermined operating distance from the pole faces beyond which it cannot be pushed by the button. This operating gap is made only little larger than the freezing gap distance so that the armature may vibrate in the region close to the gap zone in which it would be caused to freeze, but, nevertheless, stay outside the freezing zone and vibrate under the action of the normal flux fluctuations induced by the coil. By thus bringing the armature to a position where the gap is larger than the freezing zone and yet not too large, the vibrator is able to develop relatively large power in a structure small enough to be inconspicuously warm on the body of the user.

In the use of such vibrators, sound vibrations stronger than normal will often occur. In such cases the current flowing through the actuating coil **31** may momentarily become so large as to increase the flux in the gap to a value at which the armature vibrating near the border of the normal freezing zone will be pulled over by the increased flux and become frozen notwithstanding that under normal operation no such pull over will occur. Such momentary freezing of the armature is quite frequent if the operating gap of the armature is made close to the freezing zone, and very little advantage would be gained by choosing such small gaps because once the armature is frozen to the pole faces, the circuit must be cut off and the vibrator shaken to get the armature out of the freezing position.

In accordance with the invention, this difficulty is overcome to a substantial extent by preventing permanent freezing of the armature to the pole faces in the presence of excessive magnetic fluxes in the gap, and instantaneous restoration of the vibrator to the non-freezing condition upon the disappearance and passing of excessive momentary magnetic fluxes. This is effected by attaching thin flat spacers **73**, as by soldering, to the pole face **49** of the pole plate **39**, these spacers being of non-magnetic material, for instance, brass, and stopping the downward movement of the armature at a distance before it contacts with the pole faces. With such spacers, a large magnetic force produced by a speech current impulse, although it might cause momentary pulling in of the armature into the freezing zone, will not be able to produce any permanent freezing of the armature, and the armature will be free to return to normal operating position.

The vibrator of the invention is thus characterized by two special spacing arrangements, one governing the positioning of the armature during operation to secure normal operation with a relatively small gap subject to occasional freezing, but able to produce sufficiently powerful mechanical vibrations with a small structure, and the other preventing a momentary freezing action from impairing the continuity and readiness of operation of the device. By the provision of a stop fixing the normal operating position of the armature at a spacing lying just beyond the freezing zone, efficient operation is obtained with a small structure. By the provision of a second stop maintaining a minimum gap between the opposite pole surfaces in case of an occasional freezing, the close spacing is deprived of its danger without materially affecting the continuity of the operation of the vibrator unit.

In the practical construction of a vibrator of the invention, satisfactory results may be obtained by limiting the inward movement of the contact button **66** so that in the position to which the button is brought by compressing it against the body, the operating gap between the armature surface and the pole faces of the magnet core is about 3 to 4 mils. The stop members **73** should be of a thickness of about 1 to 2 mils and prevent the armature from coming near the pole faces closer than that distance. A vibrator made to operate with such gap spacing and constructed in the way shown in Figs. 3 to 7 may be made to have an outside diameter of about 60 millimeters and a height of about 25 millimeters, being thus inconspicuous and readily adapted for wear on the body of the user.

Exact adjustment of the normal operating position at which the contact surface of the button is flush with the surrounding supporting surface of the cover may be effected by turning the cover one way or another by means of ridge **62**, the nut **63** serving to lock the cover in adjusted position.

Instead of securing the armature stops **73** to the pole face **49** of the pole plate **40**, these stops may be secured to the under-surface of the armature **54** as shown at **76** in Fig. 8, the stops being attached by soldering, for instance, and having a thickness of about 1 to 2 mils as before.

In the modification shown in Fig. 9, the hole **65** within the casing is provided on its inner side with an inward projection **77** which performs the same function as the spacers **73** and **76** in the constructions of Figs. 3 and 8, respectively. As seen in Fig. 9, the upper button surface **68** is, when released, in the position indicated by dotted lines **68'** and on pressing the button against the body, the button surface is lowered to the position flush with the supporting surface **67** of the casing cover, thereby bringing the armature into the normal operating position lying close beyond the normal freezing zone. Direct contact and permanent freezing of the armature **54** to the pole faces **35** and **49** is positively prevented by the projection **77** stopping the bottom edge of the button **66**, so that a definite minimum spacing of about 1 to 2 mils is assured between the armature **54** and the pole faces, thereby securing momentary defreezing on disappearance of the excessive flux conditions that produce freezing.

In Figs. 10 to 15 is shown a modified form of a bone conduction vibrator of the invention, which is likewise used with a circuit arrangement as shown in Fig. 2. The modified type of vibrator is arranged for wear on the head of the person by means of a spring clip **80** as shown in Fig. 10, the clip holding the vibrator unit **81** with the button pressing against the mastoid bone back of the ear. The vibrator is shown in Figs. 11 to 15 and comprises an elongated casing **82** in which is mounted an electromagnet comprising a central soft iron core **84**, two L-shaped permanent magnets **85**, and a pole plate **86**, all similar to the construction shown in Figs. 3 and 4. The core member **84** and the permanent magnets **85** are held together and are clamped to the pole plate by means of a clamping strip **87** which has its ends **88** overlapping and secured by screws **89** to the underside of the pole plate **86**. The pole plate has a central opening **90** and a pole face coplanar with the pole face of the central core member **84**. Slots **90'** are provided in the pole plate to prevent eddy currents.

An exciting coil 91 is mounted on the soft iron core 84 and has a contact spring 92 that makes contact with the metallic portion of the core, and another contact spring 92 which makes contact with a contact strip 93 provided in a groove on the side of the casing and leading to the head of a terminal bushing 94 seated in the lower end of the casing 82 adjacent a second similar bushing 95 having its head contacting, by means of a spring 96, with the metallic magnetic core strap 87 and therethrough making connection to the other terminal of the actuating coil 91.

A resilient, thin diaphragm strip 96, of steel, for instance, is secured at its ends to the ends of pole plate 86 by means of screws 97 between clamping blocks 98 and adjusting blocks 99, the latter blocks being slotted to permit their shifting in longitudinal direction to adjust the active length of the diaphragm strip 96. To the center of the diaphragm 96 is secured, as by soldering, an armature plate 101 overlapping the pole face 102 of the central core and the pole face 103 of the pole plate and providing a by-pass for the flux between the two, like in the first vibrator. A vibrator button 105 is secured, by means of a rod 106 to the armature 101 of the diaphragm unit, so that upon vibration of the latter by reason of fluctuating fluxes induced by oscillatory currents in coil 91, corresponding mechanical vibrations are imparted to the vibrator button 105. The vibrator button is soldered to the end of the rod 106 and is provided with a cap 107, the external surface of which is designed to engage the bone structure to which the vibration is to be transmitted. The magnetic cores 84, 85, 86 with the diaphragm unit and the vibrator button may be assmbled as a unit outside of the casing and then placed within the casing, as shown in Figs. 11 and 12, and clamped in position by placing the cover 110 thereover and securing the ends thereof by bolts 111 to the casing ends, as shown in Fig. 14.

In the center of the casing cover 110 is provided an enlarged portion 114 having a threaded opening 115 within which is threadedly mounted a collar 116 having a central opening fitting around the vibrator button 105 and permitting longitudinal movement of the latter within the opening. The flanged outer portion 117 of the collar forms a supporting surface surrounding the contact button similar to the supporting surface 69 of the first vibrator. The position of the supporting surface 117 and the normal operating gap of the armature may be readily adjusted by turning the collar 116 in the threaded opening to the right or the left, and the collar may be locked in any desired position by locking nut 118.

The vibrator unit is held on an extension 120 of the head band 80 by means of a metallic clamp 121 having its ends secured to the rear side of the casing and constituting a sleeve into which the slightly-bent, spatula-like member 120 fits.

The normal adjustment of the collar 116 is so made that, with the actuating coil 91 energized, and the vibrator in released position, the contact button projects slightly above the supporting surface 117 of the collar, as shown in Fig. 12. Upon applying the instrument to the bone structure by means of the head band, the pressure exerted by the head band in pressing contact surface 107 of the contact button 105 against the bone structure, pushes the button inwardly until the contact surface 107 is flush with the adjacent supporting surface 117 of the collar 116. This brings the armature 101 to its normal operating position which, like in the modification described before, is just beyond, but close to, the freezing region, enabling transmission of a large vibratory power in a small size unit because of the relatively small gap. To prevent prolonged freezing of the armature to the pole surfaces 102 and 103, additional spacers 124, like the spacers 73 in Figs. 3 and 4, are provided which prevent the armature from coming into contact with the pole faces and secure immediate release of the vibratory diaphragm unit into its normal vibrating position upon the disappearance of the excessive flux.

Instead of using spacers for preventing prolonged freezing, the arrangement shown in Fig. 16 may be used, the button being mounted within a collar 116 provided at its inner side with an inward projection which limits the inward movement, like the arrangement of Fig. 9.

A vibrator so constructed will develop sufficient power for imparting intelligible sound impulses through the bone structure with a relatively small structure that permits its inconspicuous wear on the head of the user. In general, such vibrator may be made within a size of 60 millimeters length, 30 millimeters height, and about 25 millimeters width.

The invention claimed in the present application is directed to the features of the bone conduction receiver disclosed in the various exemplifications described above.

The novel combination of a bone conduction receiver with coupling means for imparting hearing-inducing vibrations to the vertebrae of the spinal column of a deafened person so as to enable him to hear without making his impairment conspicuous is claimed in my copending application Serial No. 21,706, filed May 16, 1935, as a continuation in part of the present application.

I claim:

In a portable bone conduction hearing-aid device, an electromagnetic bone conduction receiver of small size suitable for inconspicuous wear by the user comprising a magnetic core of substantial mass having a pole face, a casing enclosing said core, a magnetic armature resiliently supported by said casing at a gap spacing of the order of 2 mils adjacent said pole face, windings interlinked with said core for inducing in said gap magnetic forces imparting sound-frequency vibrations to said armature across said gap, a cover for said casing having an opening facing said armature, a contact member extending from said armature having an external contact surface projecting through said cover opening for engaging hearing-inducing bone structure of the user, and resilient supporting means for carrying said receiver in a floating condition and pressing the contact surface of said contact member against hearing-inducing bone structure while said contact member is subjected to forces tending to freeze said armature to said pole face, and means for adjustably locking said cover in a position at which the portion of the cover adjacent said opening limits the inward movement of said contact member to a position in which said gap is maintained at a sufficiently small length for producing by the action of the floating mass of said receiver hearing-inducing vibratory forces imparted to said bone structure without freezing said gap.

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