

Feb. 28, 1967

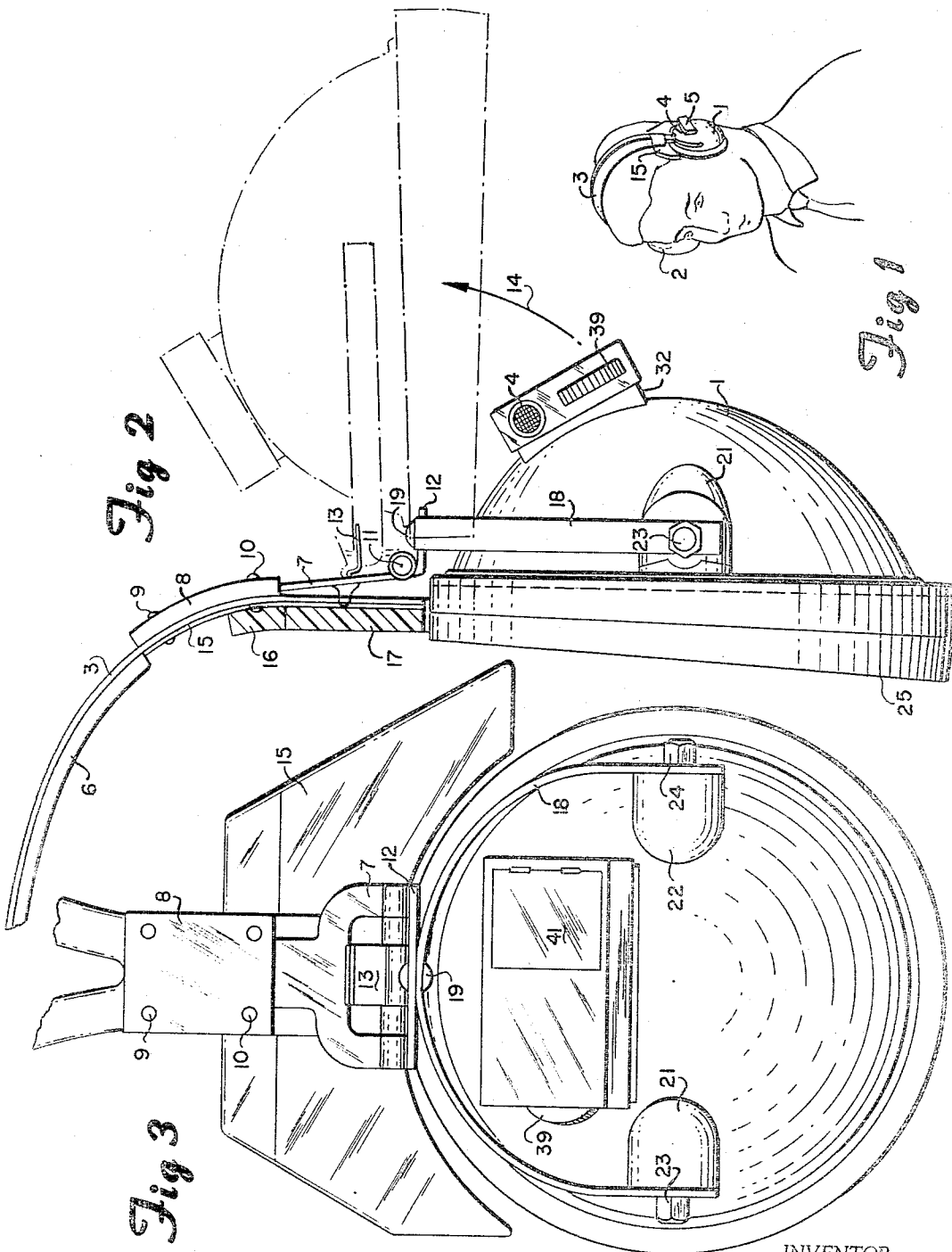
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3,306,991

PROTECTIVE HEARING AID

Filed June 4, 1963

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

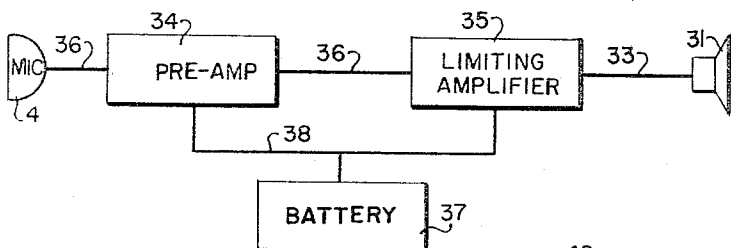


Fig 7

Fig 8

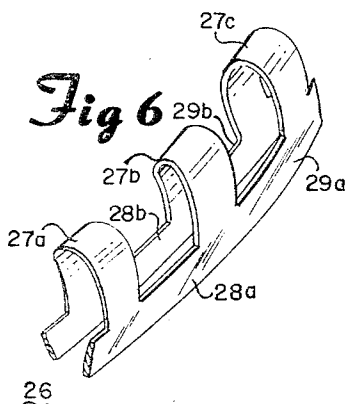
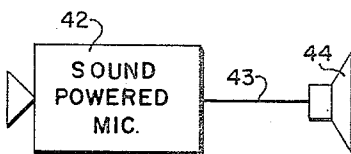


Fig 6

Fig 5

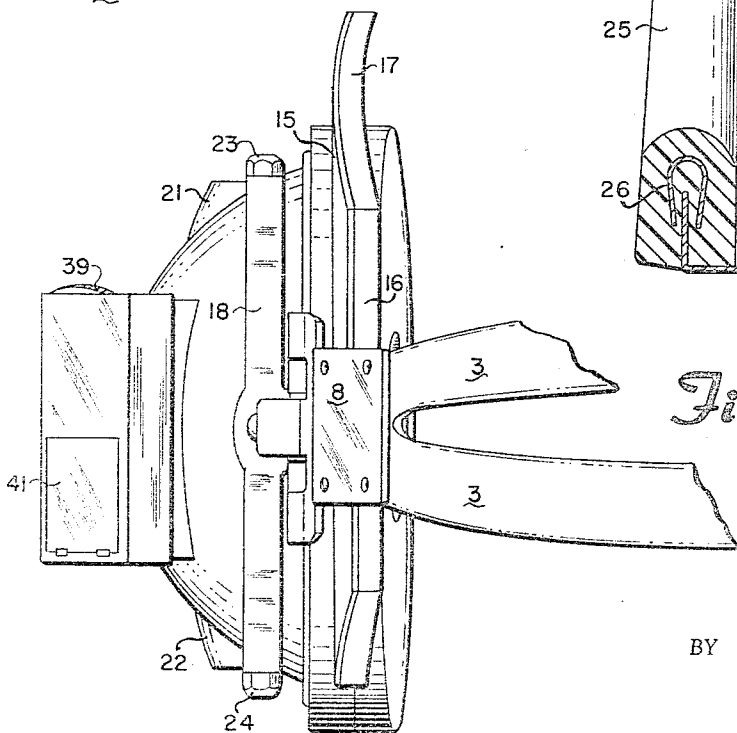
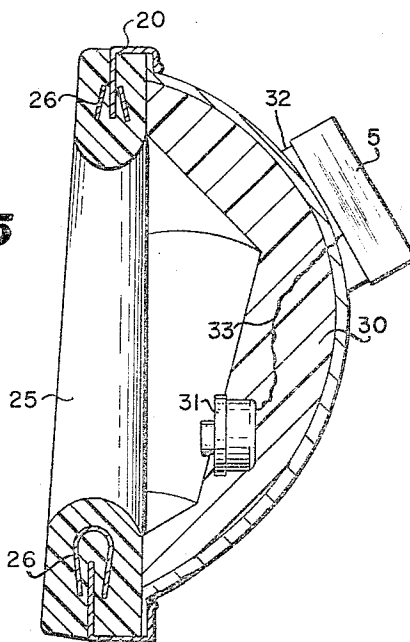


Fig 4

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1

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PROTECTIVE HEARING AID
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Filed June 4, 1963, Ser. No. 285,466
6 Claims. (Cl. 179-107)

This invention relates to protective hearing aid apparatus and more particularly to apparatus for protecting the human ear from injurious noise, yet which will permit sounds of safe amplitudes to be heard between intermittent or unpredictable periods of excessive noise.

There are situations in industry, in the military services, and in commercial aviation, where persons must be exposed to sounds having levels in excess of those which may damage hearing. Under these conditions, damage to hearing can usually be avoided by having the individual exposed to the noise wear one or more ear protective devices. There are three general classes of ear protectors: (1) earplugs that fit into the ear canal; (2) earmuffs, covers or cushions that fit over the external ear and under which earplugs may be worn; and (3) rigid helmets that fit over the entire head and under which earplugs and earmuffs may be worn.

Investigations have shown that a great deal of deafness could have been avoided by proper protection from high noise levels. As a consequence, industry has recognized the need for protection against high intensity sound and it is common to provide employees required to work in areas of high ambient noise with the above-mentioned protective devices. The means involved heretofore have been of limited value; in particular, simple earplugs are of limited value because they do not inhibit sound transmission by bone conduction. In order to achieve adequate reductions in sound pressure levels it is necessary to have a good airtight seal between the ear protector and the surfaces of the ear or head against which it bears. Also, prior devices have inhibited normal hearing to the point that verbal communication is extremely difficult if not impossible.

The amount of protection afforded by an ear protector or combination of protectors is measured in terms of the number of decibels it attenuates or reduces the intensity of sound that is transmitted through it. In general, the higher frequency components in a noise are attenuated more than are the lower-frequency components.

Ear protectors reduce the level of speech or other wanted signals to the same degree that they reduce the noise. In some situations, therefore, the reception and understandability of speech in the presence of other signals is adversely affected. To overcome this difficulty various means have been attempted; for example, ground service personnel at airports, wearing ear covers or acoustical helmets, sometimes employ "walkie-talkie" radio transmitters for communication.

Hunters and especially skeet shooters, frequently suffer ear damage from gun blasts, but hearing impairment is often so gradual that it goes unrecognized until serious damage occurs and only recently has attention been given to it as a serious problem.

By the present invention, there is provided an acoustic barrier between the ear and the source of ambient noise and which has an electro-acoustical transmission system through which controlled amounts of sound may be transmitted to the ear. That is, the system includes means for limiting maximum excursion of the amplitude of signals transmitted through the acoustic barrier. By this means, all sounds exceeding a given maximum amplitude may be attenuated to safe levels, whereas all sounds below the given amplitude level may be transmitted with negligible attenuation.

2

In a typical embodiment, the apparatus comprises a pair of protective ear covers having an electro-acoustic sound transmission system resembling, in general, a conventional hearing aid which will pick up external sounds via microphone located exteriorly of the ear covers and transmit the sounds to an earphone inside the ear covers. The dynamic range of the microphone-earphone system is limited so that only sounds below a given amplitude will reach the ear. Since the transmission characteristics of the apparatus are non-linear, low-level sounds will not be attenuated to any significant extent.

It is, therefore, a principal object of this invention to provide novel and improved means for protecting the ear against potentially harmful high-intensity noise yet which will not interfere with normal speech or other communication.

Another object of the invention is to provide novel and improved means for transmitting only those sounds through an acoustical barrier which do not exceed a given maximum intensity.

Another object of the invention is to provide novel and improved protective hearing aid having a microphone located exteriorly of an acoustic barrier for picking up ambient sounds and an earphone located at the ear within the barrier for reproducing the sound picked up by the microphone, and an amplifier therebetween for restricting the sound transmitted from the microphone to the earphone to levels below a given maximum intensity.

Still another object of the invention is to provide a novel and improved ear protector of the type to be worn over the external ear, and which may easily be moved into or out of place without the necessity of completely removing the apparatus from the head of the wearer.

Yet another object of the invention is to provide a novel and improved protective ear cover which may readily be formed or molded to conform to the particular head contour of an individual and thus provide a substantially air-tight seal between the ambient air and the ear.

Another object of the invention is the improvement of ear protectors, generally.

Other objects and features of the present invention will be readily apparent to those skilled in the art in the following specification and accompanying drawings wherein is illustrated the preferred form of the invention in which:

FIGURE 1 is a perspective view of the protective hearing aid of the invention showing the manner in which it is usually worn.

FIGURE 2 is a fragmentary front elevational view showing one half of the apparatus of the invention.

FIGURE 3 is a side elevational view of the apparatus of FIGURE 2.

FIGURE 4 is a top plan view of the apparatus of FIGURES 2 and 3.

FIGURE 5 is a cross-sectional view of a portion of the apparatus of FIGURE 2.

FIGURE 6 is a fragmentary perspective view of the stiffening rib portion of the apparatus of FIGURE 5.

FIGURE 7 is a simplified block diagram of a first embodiment of an electro-acoustical transmission system which may be used in the invention.

FIGURE 8 is a simplified block diagram of a second embodiment of an electro-acoustical transmission system which may be used in the invention.

Referring now to FIGURE 1, the apparatus comprises an acoustical barrier in the form of a pair of ear covers 1 and 2 supported by headband 3. Ambient sounds are blocked by ear covers 1 and 2 so that they cannot reach the ears directly. However, microphone 4, carried within amplifier 5, will pick up ambient sounds and transmit them, at controlled levels to an earphone located within the ear cover 1. It should be understood that either ear

cover 1 or ear cover 2 may be provided with the microphone-amplifier-earphone combination, or if desired, both ear covers may be so provided and thereby permit bin-aural or directional hearing effects to be obtained.

In the preferred embodiment to be described herein-
after, the apparatus is the same for both ears and there-
fore is symmetrical about a vertical plane passing through
the center of headband 3. For this reason, only one half
of the device is shown in FIGURE 2, it being understood
that the half not shown is substantially the same for the
other ear.

Looking now at FIGURE 2, the apparatus comprises
a headband 3, the undersurface of which is provided with
a resilient cushion 6. Headband 3 is preferably fab-
ricated from spring steel and is slidably attached to yoke
7 by means for a sliding telescopic joint including block
member 8 and a plurality of rivets, two of which (9 and
10) are shown in FIGURE 2. This arrangement will
permit the ear cover to be raised or lowered to fit the
heads of various wearers. Yoke 7 is rigidly attached to
slidable block member 8 and its lower end carries relief
hinge 11 which pivotally supports bracket 12.

The lower end of headband 3 is attached to plate 15,
the inwardly facing surface of which carries pads 16
and 17. Pads 16 and 17 are fabricated from any suit-
able resilient material, such as foam rubber or plastic,
and may be adhesively bonded to plate 15. These pads
(16-17) rest against the head of the wearer above the ex-
ternal ear and, together with cushion 6, support the device
on the wearer's head. Detent spring 13 is attached to
yoke 7 via suitable fastening means. Detent spring 13
will engage the end of bracket 12 when yoke 7 is turned
upward about the axis of relief hinge 11. This hinged
arrangement permits the ear cover to be swung upward,
as indicated by arrow 14, to the position indicated in
dotted outline. Thus, the ear cover may be removed from
the wearer's ear while the remainder of the assembly con-
tinues to grip the head by means of the supporting pads
16-17. As can be seen in FIGURES 3 and 4, plate 15
and pads 16-17 extend rearwardly and downwardly to
provide a relatively large surface area which bears against
the wearer's head. This arrangement makes the device
more comfortable by distributing the weight of the device
over a relatively large area and also serves to support
the apparatus when the ear covers are turned upwardly
or retracted from the ears. Ear cover 1 is supported from
bail 18 which in turn is pivotally attached to yoke 7 by
suitable fastening means such as rivet 19. Bail 18 is
pivotally attached to bosses 21 and 22 (see FIGURE 3)
on ear cover 1, by means of fasteners 23 and 24. The
external shell portion of ear cover 1 may be fabricated
from metal, Fiberglas, plastic or other materials capable
of blocking the transmission of airborne sounds. The
inwardly facing surface of ear cover 1 is provided with a
cushion seal 25.

As stated hereinabove, to provide the necessary sound
exclusion it is necessary to have an airtight seal between
the ear cover and the head of the wearer. Seals used in
protective ear covers heretofore have not been al-
together satisfactory. Cushion seal 25 of the present in-
vention provides a comfortable yet efficient seal between
the ear cover 1 and the wearer's head. Cushion seal 25
may be fabricated from foam rubber or plastic or other
soft yieldable material. This seal features a soft metal
"back-bone" or stiffening rib 26 which is embedded as
shown in FIGURES 5 and 6, and which permits the con-
tour of the cushion seal 25 to be molded to fit the ir-
regular contours of various wearers' heads. That is,
stiffening rib 26 is preferably fabricated from a relatively
soft metal which can be readily bent or formed to es-
tablish the outline configuration of the cushion seal 25
within which it is embedded. Protective ear covers used
heretofore represent compromises between the shell or
ear cover profile and a flexible surface to fit a variety
of head contours. Any deviations from the molded shape

of the seal must therefore represent distortion of the
sealing ring from its natural shape. In practice, it has
been difficult with prior devices to provide sufficient
flexibility in the seal without losing the ability to shield
against blast and low frequency sounds. Also, a further
disadvantage of prior devices is their inability to fit the
contour deviation imposed by the frames of eyeglasses.

In the present invention, the cushion seal 25 is re-
latively soft and flexible yet will permit the basic seal
shape to be modified by distorting the stiffening rib 26
which may be considered as a series of U-shaped tabs
27a, 27b, 27c, etc. connected by metal strips 28a, 28b,
29a, 29b, etc. This rib arrangement provides the desired
firmness of the overall seal, yet will allow small contour
variations to be accommodated. Thus, the amount of
elasticity in the seal required to fit regular contour devia-
tions is minimized.

In the preferred embodiment the cushion seal behaves
as if it were made of modeling clay, which is capable of
resisting a substantial force after molding and would
thereafter retain the molded shape. This cushion seal
results in a substantially airtight juncture between the
protective shell of the ear cover 1 and the head of the
wearer with much less pressure on the wearer's head
than prior devices and contributes greatly to the wearer's
comfort.

A disadvantage of prior protective ear covers is that
if the user desires to temporarily remove the ear covers,
as in the temporary absence of high level ambient noise,
the user will commonly pull the head set down around
the neck; this results in discomfort and is otherwise
inconvenient. The relief hinge feature described herein-
above, makes it possible to wear the apparatus comfort-
ably in the protective position and yet very quickly un-
cover the ears when desired.

The interior of ear cover 1 is lined with a sound ab-
sorbent material 30 which may consist of foamed plastic,
felt or other fibrous material, or other suitable sound
absorbent substances.

Cushion seal 25 is provided with a central aperture
of a size sufficient to encircle the outer ear. Cushion
seal 25 is attached to ear cover 1 by means of an annular
metal clip 20 which is partially embedded within the
seal material and a portion of which extends around and
engages a flanged portion of the periphery of ear cover 1,
as shown in FIGURE 5. As will be apparent to those
versed in the art, means other than clip 20 may be used
to attach cushion seal 25 to ear cover 1. Sound absorb-
ent material 30 has embedded therein an electro-acoustical
transducer 31 which may be a miniature loudspeaker, an
earphone, or the like.

The exterior of ear cover 1 is provided with a suitable
mounting bracket 32 which is used to support the micro-
phone 4 and amplifier 5. Leads 33 connect transducer
31 with amplifier 5. The amplifier housing includes
microphone 4 which is used to pick up ambient sounds.
The output of microphone 4 is amplified and transmitted
to transducer 31 via leads 33. A combination switch
and volume control 39 may be included in the amplifier
circuit. A simplified block diagram of the electrical
signal transmission system is shown in FIGURE 7. Mi-
crophone 4 connects to pre-amplifier 34 via lead 36;
the output of pre-amplifier 34 is supplied to limiting ampli-
fier 35 via lead 36. The output of limiting amplifier 35
is supplied to transducer 31 via leads 33. Access door
41 is provided to permit replacement of the battery.
Operating power for the apparatus is supplied from bat-
tery 37 via lead 38. Inasmuch as each of the functions
of the units represented by a rectangle in the block
diagram (FIGURE 7) may be any one of the numerous
circuits for each respective function well-known in the
art, it is deemed unnecessary to show circuit details.
Preferably, the circuit embodies semiconductor elements
in order to obtain the advantages of low-power consump-
tion and very small size. It is believed that the descrip-

tion of the electro-acoustical signal transmission system is sufficient for those versed in the art to practice it. However, reference may be made to Patent No. 2,327,321 for a detailed description of a suitable system which shows an automatic gain control in a hearing aid amplifier.

In this connection, it should be understood that practical limitations imposed on transducers such as earphone transducer 31 and/or microphone 4 limit their dynamic range. This limitation in dynamic range will not make it possible to transmit sound pressure levels through the system which are of sufficient intensity to cause hearing impairment.

Two basic criteria have been obtained from research on hearing loss due to exposure to high intensity sound. One criterion applies to sounds that are pure tones or the sounds that contain most of their energy in narrow, so-called critical bands. Critical bands vary somewhat in width as a function of frequency but approximately 100 cycles per second wide for most of the audible range of sound frequencies. The second criterion applies to wideband noise, in which the energy is spread over an octave or several octave bands. The microphone-amplifier-earphone system has practical limitations in transmitting either high-intensity narrow-band sounds or wideband sounds of any intensity. Based on industrial surveys, values have been determined for the maximum pressure level a sound can possess for both wideband noise and for pure tones or critical bands of noise, that a sound can possess if persons are not to suffer a possible hearing loss. These criteria are called damage risk criteria for hearing. While many persons can be exposed to greater intensities than the established damage risk criteria, without suffering any appreciable hearing loss, these values have been established as base for virtually all persons. In summary, it is the function of the electro-acoustical transmission system portion of the invention to attenuate sounds exceeding the established damage risk criteria for human hearing. The structural characteristics of the electro-acoustical transmission system may take a number of forms. For example, a microphone-amplifier-earphone system as described hereinabove may resemble a conventional hearing aid with the possible exception that the circuit may be provided with an automatic gain control or volume limiting feature. A circuit of the automatic gain control type continuously adjusts the gain or loss in the transmission system to restrict the transmitted sound energy to levels below the damage risk criteria. Circuits suitable to perform these functions are well known to those versed in the art.

Various modifications to the above described embodiments may be made. For example, the amplifier and battery may be omitted by using a "sound-powered" telephone type of system in which the microphone directly energizes the earphone. Since the area of the sound-responsive diaphragm in the microphone may be made larger than the area of the moving element in the earphone or the eardrum, transmission losses may be made negligible in a sound-powered system. Thus, it becomes feasible to construct a practical system without having a powered amplifier. There is shown in FIGURE 8 a simplified block diagram of a sound powered system comprising sound powered microphone 42 which is connected via line 43 to earphone 44. Limiting and/or automatic gain control means may be readily inserted in line 43 of the sound powered system, if desired, as will be apparent to those skilled in the art.

In the foregoing description, reference has been made to an externally mounted microphone. It should be understood, however, that the microphone need only be responsive to ambient sounds or those sounds which originate exteriorly of the ear-enclosing barrier. Thus, the microphone may, if desired, be housed within the

ear cover so as to have its sound responsive element or diaphragm exposed to ambient sounds through an aperture or port in the ear cover. Other modifications of the mounting arrangement of the microphone-earphone system will be apparent to those skilled in the art.

While preferred embodiments of the present invention have been specifically disclosed, it is to be understood that the invention is not limited thereto as many variations will be readily apparent to those skilled in the art and the invention is to be given its broadest possible interpretation within the terms of the following claims.

What is claimed is:

1. A protective hearing aid comprising in combination:
 - a headband adapted to be worn on the head;
 - a pair of sound excluding ear covers supported by said headband to enclose the outer ears of the wearer;
 - microphone means responsive to sounds originating exteriorly of said ear covers;
 - sound reproducing transducer means responsive to said microphone means to reproduce sounds picked up by said microphone means interiorly of at least one of said ear covers, a limiting amplifier to control said reproduced sounds within a finite dynamic range, the upper limit of which is below the damage risk criteria for human hearing;
 - means on the external surface of one of said pair of ear covers for mounting said microphone means; and
 - means mounting said reproducing transducer means on the interior of said one ear cover.
2. A protective hearing aid as defined in claim 1 wherein said headband comprises:
 - a relatively fixed supporting member crossing over the top of the wearer's head and a pair of relief hinges at either end of said member to which said ear covers are attached; and
 - detent means which, in conjunction with said relief hinges, will permit said ear covers to be angularly positioned from a first position enclosing said outer ears to a second position in which said ear covers are retracted from said outer ears.
3. A protective hearing aid as defined in claim 1 wherein said ear covers each include cushion seal means comprising:
 - a relatively soft, yieldable cushion, within which is embedded an annular stiffening rib adapted to be formed by external force to a relatively fixed shape which will establish the normal external contour configuration of said cushion.
4. A protective hearing aid comprising:
 - a headband adapted to be worn on and over the top of the head;
 - a pair of relief hinge means, one each of which is dependent from a corresponding end of said headband;
 - a sound-excluding ear cover pivotally supported by each of said hinge means and adapted to enclose the outer ears of the wearer;
 - a microphone responsive to sounds originating exteriorly of said ear covers;
 - bracket means secured to the external surface of one of said ear covers effective to mount said microphone above the horizontal center line of said one ear cover;
 - a sound reproducing transducer mounted within at least one of said ear covers;
 - a sound absorbent liner disposed adjacent the interior wall of said one ear cover for mounting said transducer; and
 - a limiting amplifier interconnecting said microphone and said reproducing transducer for transmitting

7

sound signals from said microphone to said transducer, said limiting amplifier having a maximum dynamic range which is less than the damage risk criteria for human hearing.

5. A protective hearing aid as defined in claim 4 including detent means adapted to selectively restrain said ear covers in a retracted position away from said outer ears.

6. A protective hearing aid as defined in claim 5 wherein said ear covers each include cushion seal means comprising:

a relatively soft, yieldable annular ring within which is embedded an annular stiffening rib adapted to be selectively formed to establish the normal external contour configuration of said ring.

8

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