

[54] SELF-SHAPING EARPLUGS
[76] Inventor: Allen William Mills, 11 College Avenue, Arlington, Mass. 02174
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[21] Appl. No.: 53,384
[52] U.S. Cl. 128/152
[51] Int. Cl. A61f 11/02
[58] Field of Search 128/151, 152; 2/209, 2/2; 181/23, 33; 264/222

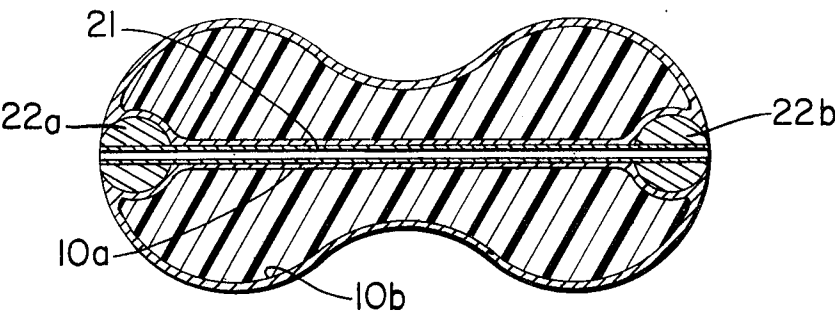
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[57] ABSTRACT
An earplug preferably having a dumbbell shape and preferably of an elastic material, a filler contained therein to attenuate audible sound but plastic enough to be deformed, and a stiffening member at the axis of the earplug to assist in inserting the earplug into the ear canal.

14 Claims, 11 Drawing Figures



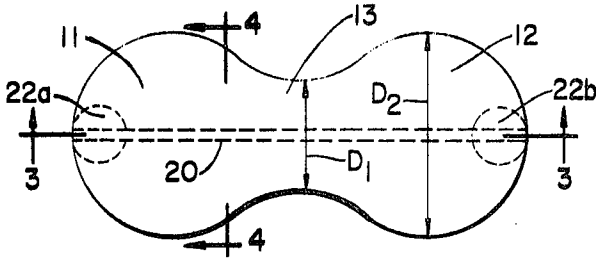


FIG. 1

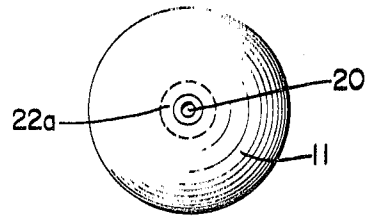


FIG. 2

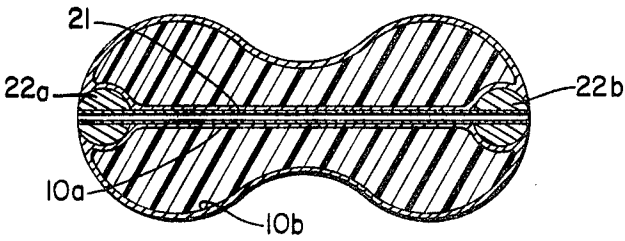


FIG. 3

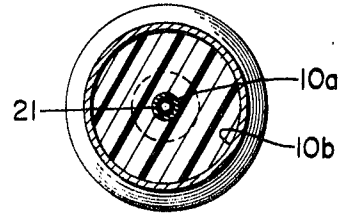


FIG. 4

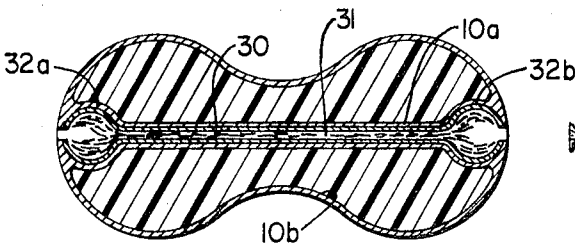


FIG. 5

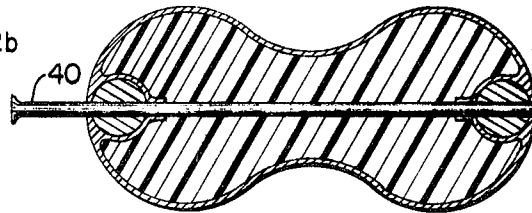


FIG. 6

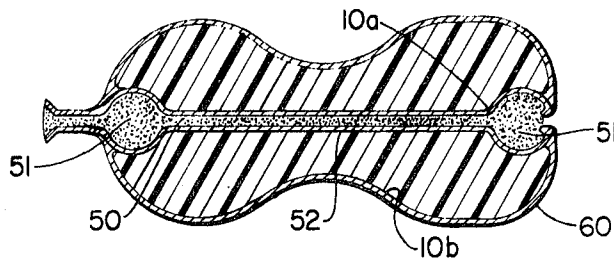


FIG. 7

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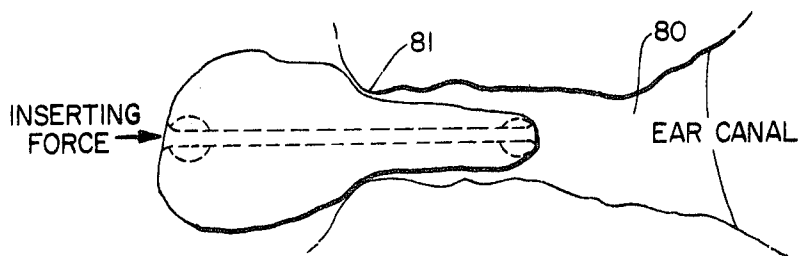


FIG. 8

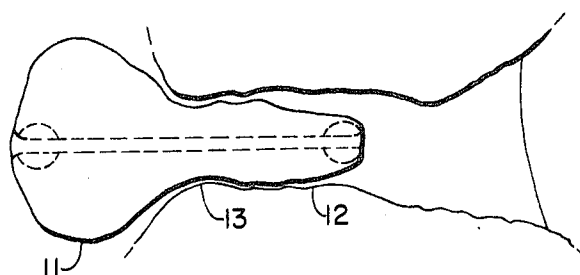


FIG. 9

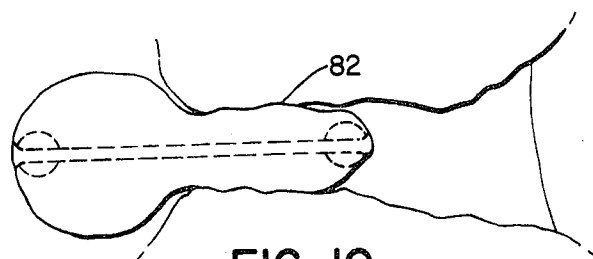


FIG. 10

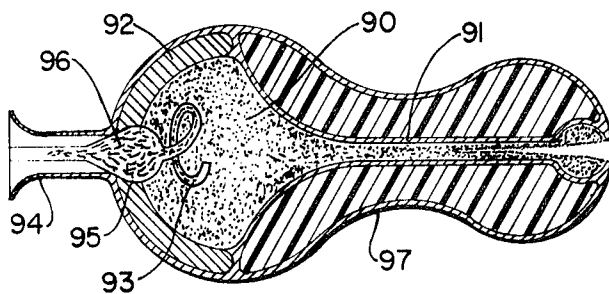


FIG. 11

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SELF-SHAPING EARPLUGS

This invention relates to noise suppression or noise attenuating devices and is more particularly directed to a new and improved self-shaping earplug. Noise in the audible frequency range continues to cause a serious problem for those in close proximity to the noise source. For example, those firing rifles, artillery and the like often experience a serious hearing loss after being exposed to the noise associated with the firing of these weapons. In addition, ground personnel working in the vicinity of aircraft, particularly jet aircraft, continuously encounter jet engine noise which has in the past seriously affected the hearing of these individuals, particularly when exposed to this noise over a long period of time.

Various means have been developed for impeding the transmission of noise in the auditory canal. They have included earplugs of various configurations and types as well as ear muffs. These devices provide a substantial amount of attenuation at frequencies between 1,000 and 10,000 Hz (Hertz) but are much less effective at the lower frequencies which appear to be a major cause of hearing loss. The difficulties with the prior art earplugs appear to be primarily in the fact that there is not a sufficient area of contact made by the outer surfaces of the earplug with the flesh of the auditory canal and in that they are difficult to insert completely into the ear. In order to overcome the difficulties of the prior art, a new and improved earplug construction was required. The earplug must be easily insertable into the auditory canal, be securely held therein, and also make sufficient compressive contact with the flesh lining the ear canal.

The above has been accomplished in its most preferred form by the provision of an envelope of highly elastic material having two cavities coupled together through a constriction or commissure and enclosing a filling of a material which is stiff under transient forces, such as audible sound pressures, but highly plastic under forces that continue to act in the same direction for periods of time very much longer than the periods of audible sound. The earplug envelope is most preferably constructed in the shape of a dumbbell which includes two cavities connected by a commissure. The major axis of this dumbbell is formed of a more or less cylindrical member which is stiff enough to transmit an inserting force to place the earplug into the auditory canal. The earplug is constructed such that one partially compressed cavity is placed into the auditory canal and is then filled with filler from the other cavity positioned outside the auditory canal.

In view of the above, it is an object of this invention to provide a new and improved noise attenuating and selfshaping earplug.

A further object of this invention is to provide a new and improved earplug which will fit tightly into the outer portion of the auditory canal without causing undue discomfort to the user.

An additional object of this invention is to provide a new and improved earplug which is adapted because of the stiffener provided therein to be easily inserted into the ear canal.

Another object of this invention is to provide a new and improved earplug which provides great attenuation of sound at both low and high frequencies.

Further objects and advantages of the invention will in part be obvious and will in part be apparent in the specification. The invention accordingly comprises an article of manufacture possessing the features, properties and the relation of elements which will be exemplified in the article hereinafter described and the scope of the invention will be indicated in the claims.

For a fuller understanding of the nature and objects of the invention, reference is had with the following description taken in conjunction with the accompanying drawings in which:

FIG. 1 is a top view of the preferred form of the earplug according to the invention;

FIG. 2 is an end view of the earplug shown in FIG. 1;

FIG. 3 is a sectional view taken along line 3—3 in FIG. 1 which shows a preferred construction in greater detail;

FIG. 4 is a sectional view taken along line 4—4 in FIG. 1;

FIG. 5 is a sectional view showing the central tube portion filled with a substance to prevent the passage of sound through the tube;

FIG. 6 shows in a sectional view according to the invention a solid rod rather than a hollow tube including means to pull the earplug out of the ear canal;

FIG. 7 shows in a sectional view an earplug having foamed stiffening member;

FIGS. 8—10 show the preferred form of the earplug according to the invention being inserted into the ear canal of an individual;

FIG. 11 is a sectional view of another earplug embodiment.

Reference should now be had to FIGS. 1—5 for a description of the preferred embodiment of the earplug according to this invention. The earplug is preferably constructed substantially in the shape of a dumbbell or other similar shape and includes two substantially hollow and preferably spheroid cavities at 11 and 12 which are coupled together through a constriction, neck, or commissure 13. The earplug retains its initial shape except when stressed and employed as shown in FIGS. 8—10.

The constriction is essentially a tube which permits the flow of filler material between the cavities 11 and 12. Although the cavities 11 and 12 are shown in the shape of spheroids, it is to be understood that for the purposes of this invention that the term spheroid is intended to include ellipsoids as well as other irregular shapes which approximate the shape of the ear canal in that portion lying close within its entrance. It should also be understood that cavities 11 and 12 need not be of the same shape as long as they function as described herein.

In its preferred form, the earplug cavities as well as the constriction are formed of an envelope of highly elastic material such as natural latex or rubber, preferably a very thin wall of said material, such that it may stretch a substantial amount, yet be strong enough to return to its original shape after being stretched.

It is to be understood that other materials such as synthetic rubbers and plastics and the like having highly elastic properties can also be used to form the walls of the cavities as well as the commissure, although the commissure can be constructed of a non-elastic material if desired. The envelope comprises an inner wall shown at 10a and an outer wall shown at 10b. In its preferred construction, the earplug is hollow through its

major axis much the same as a doughnut. It should be understood that instead of an inner wall 10a being provided, the earplug can be made with only an outer wall, although for the purposes of this invention as will be seen in the further description of FIG. 1, it is preferable that a hollow portion be provided along the central axis of the earplug. Positioned within the hollow portion of the earplug and functioning as the major axis thereof is a stiffening means or member (e.g., of polyethylene, other plastics or metal) 20 which is preferably bonded to the envelope of the earplug. Bonding can be accomplished between the inner wall 10a and the stiffening member 20 by adhesives or by the provision of heat seals between the stiffening means 20 and the wall of the envelope. The stiffening means 20 is preferably stiff enough to transmit an inserting force to the spheroid cavity being inserted into the ear canal thus pulling (by stretching the cavity wall) and not primarily pushing the earplug into the ear canal. The stiffening means is on the other hand most preferably flexible enough so that discomfort is not caused to the user as the earplug is being inserted. The envelope is preferably bonded or fixedly coupled to the stiffening means so that the earplug envelope will not slide with respect to the stiffening means when the earplug is being inserted into the ear canal.

In the preferred embodiment, the stiffening means is preferably in the shape of a tube 21 which extends from one end of the envelope to the other end of the envelope (axially) and is supported at either end by two solid members 22a and 22b having bores for receiving the ends of the tube 21. The members 22a and 22b are constructed of hard plastic or metal or may be molded enlargements of the same material as the tube 21. The hollow tube 21 provides an intentional pressure leak through the earplug to reduce discomfort due to air pressures upon the tympanic membrane of the ear associated with the insertion of and removal of the earplug and also to reduce discomfort due to changes in barometric pressure while the earplug is being worn. In effect the stiffening means or member incorporates means for venting a sustained pressure differential from one end of said earplug to the other while providing substantial attenuation of audible acoustic energy. Preferably the tube is coupled to one or both of the members 22a and 22b so that there will not be any sliding between the tube 21 and the members 22a and 22b. In the alternative, a sleeve can be placed over the tube to engage the members 22a and 22b to maintain spacing between the members.

In addition, it is preferable that the inner wall 10a of the envelope substantially surround the members 22a and 22b except for the tube openings so as to help retain the stiffening member in position. It should be understood that the tube 21 could be shorter than that shown and instead of extending through the bore members 22a and 22b could only partially extend through the bores or alternatively the tube could be connected to the outside of the members 22a and 22b as long as there is an air passage from one end of the earplug envelope to the other end of the earplug envelope.

In order to attenuate the passage of sound into the ear canal there is provided as an acoustical barrier a filler material within the cavities 11 and 12 as well as within the commissure 13. The filler material is selected to be stiff or relatively unyielding under transient forces (oscillatory acoustical pressures) such as audible

sound forces, but highly plastic and displaceable under forces or relatively sustained pressures that continue to act in the same direction for periods of time very much longer than the periods of audible sound. Suitable materials include soft waxes, gels, or plastic materials such as silicone resins.

In practice, materials which are known generally in the art as silicone putties have been found to be most acceptable because of their unusual mechanical properties. Examples of such silicone putty are disclosed in U.S. Pat. Nos. 2,541,851; 2,546,036; 2,801,423; 2,644,805; 2,899,683; 3,177,176; 3,350,344. In addition, other materials such as a paste-like material, for example as shown in U.S. Pat. No. 2,990,553, can also be used although the silicone putty type materials are most preferred because of their highly unusual combination of transient elasticity and long-term plasticity.

In the most preferred embodiment, that is when the cavities 11 and 12 are in the shape of a spheroid, it is preferable that the diameter D_2 of the spheroid cavities is related to the diameter D_1 of the commissure of constriction such that there is permitted a flow of filler material between the cavities after one cavity is compressed and inserted into the ear. Most preferably D_2 should be approximately equal to 0.5 to 0.8 of the diameter D_1 . When cavities 11 and 12 are in the shape of an ellipsoid or other irregular shapes, it has been found that the major diameter or largest diameter D_2 of the ellipsoids or other irregular shapes should be related to the diameter D_1 of the constriction by the same preferred ratio.

It has also been found that the earplug provides substantial attenuation as well as being easily usable by an individual without irritating the ear canal if the length of the commissure is equal to 0.15 to 0.35 of the length of either cavity. For an adult male a suitable earplug, by way of example only, can be constructed with cavities 11 and 12 of diameters about 10mm, the commissure diameter 6mm, an overall length of 22mm, a commissure length of 2mm and the length of each cavity 10mm. The filler used was silicone putty such as sold by Dow Corning Corporation.

The tube 21 was constructed of polyethylene, the tube having an inside diameter of about $\frac{1}{2}$ mm and a wall-thickness of about $\frac{1}{2}$ mm. The tube was stiff along its longitudinal axis but was flexible enough to permit it to bend. The outer spheroids were constructed of lead and were 4mm in diameter in one embodiment of the invention, and in another preferred embodiment of the invention, were constructed of enlargements 3mm in diameter formed out of the material of tube 21 as shown in FIG. 5.

To construct the earplug according to the invention, it has been found convenient to first form the stiffening member and thereafter dip this assembly into a latex mixture to form the inner wall 10a of latex. Thereafter the filler material in the form of putty is molded thereon in the desired shape leaving the latex uncovered only at either end of the stiffening member. The assembly is again dipped into the latex mixture to form the outer wall 10b of the dumbbell. Other conventional methods of manufacturing the earplug could be utilized such as the molding techniques all of which are well known in the art.

It has been found in practice that equalization of air pressure on either side of the earplug can be achieved with a hollow tube if the aperture is partially occluded

by silicone grease, oil or other highly viscous liquid as shown at 31 in FIG. 5. The grease or fluid will move within the tube a sufficient distance to permit equalization of air pressure on either side of the earplug while at the same time providing an acoustical block.

In FIG. 5 there is also shown an alternate configuration of a stiffening member 20 according to the invention. In this configuration a tube 30 is provided with hollow bulges 32a and 32b at either end thereof. These hollow members serve to store additional quantities of the grease or viscous liquid and thereby to ensure that the aperture of tube 30 is always sufficiently occluded to prevent the passage of audible sound. In this construction the tube can be fabricated using molding techniques or in the alternative the tube 30 can be heated at either end in a manner such as to construct the enlarged end pieces.

Reference should now be had to FIG. 6 which shows a different configuration of a stiffening member. Instead of a tube for use as the stiffening member as shown in the prior figures, a solid rod of flexible but stiff material, that is stiff along the longitudinal axis, is provided to permit the earplug envelope to be easily inserted within the auditory canal.

In FIG. 6 the envelope of the earplug is constructed such that no inner wall 10a of elastic material is provided and the filler is in direct contact with the rod.

As shown in FIG. 6, the rod also includes an extension shown at 40 to facilitate the removal of the earplug from the auditory canal. It is to be understood that the puller or extension 40 can also be incorporated as part of the tubes shown in FIG. 1 through 5 by providing extensions thereon. The extension in that case would also preferably be hollow.

Another alternative construction of the earplug employs a stiffening rod or tube made of a foamed plastic material as shown in FIG. 7. Suitable materials to construct the stiffening member are resins such as polystyrenes and polyurethanes.

The use of a foam plastic tube or rod permits the latex to enter into the pores of the foam and provides a good mechanical bond between the inner wall 10a of the envelope and the foamed stiffener member. The foamed stiffener member is particularly shown at 50 and includes the spheroid of substantially spheroid portions 51 with a central portion 52. The use of a foamed tube provides additional advantages when a glob of silicone oil or grease or other viscous material is inserted into the tube as described with reference to FIG. 5.

The inner porous walls of the tube provide a means for storing and retaining the viscous material within the tube due to the adhesion between the viscous fluids stored in the inner pores of the tube and the remaining portion of the viscous material positioned within the aperture of the tube. The foamed stiffening is most preferably an open celled structure providing large surface areas on both the inside and outside of the tube. The foamed structure of the inside of the tube provides an acoustical micro-labyrinth having high resistance to the passage of audible sound but permitting equalization of barometric pressures.

FIG. 7 also shows at 60 an alternative shape of the cavity to be inserted into the ear canal, which shape, being blunter-tipped, is better adapted than a perfect sphere to maximize the area of contact between the earplug and the flesh lining the ear canal.

FIGS. 8-10 show the manner in which the earplug of this invention is inserted into the ear canal. The ear canal is generally shown at 80. The mouth of the canal is generally shown at 81. In FIG. 9 the earplug is shown being initially pulled into the ear canal. To facilitate insertion of the earplug, one of the cavities is initially squeezed down such that it is a pointed shape as shown in FIG. 8. This compression will cause the filler material in the earplug to expand the other cavity as shown in FIG. 9.

In FIG. 9 the earplug is shown inserted sufficiently that the commissure or constriction is now about the mouth of the auditory canal such that one cavity 11 is completely outside the mouth and the other cavity 12 is within the ear canal. After a short period of time as shown in FIG. 10 the elasticity of the envelope causes the filler material to flow or be driven back into the cavity 12 from the cavity 11 and thereby cause the cavity 12 to expand such that the outer wall thereof makes intimate contact with the thin, stiff layer of flesh lining the boney auditory meatus, of the ear canal shown at 82. In this manner a substantial improvement of attenuation is achieved because of the close mechanical coupling of the earplug with the boney auditory meatus. In earplugs of the prior art, this feature has not been provided since they have not been made long enough to penetrate into and make compressive contact with a substantial portion of the meatus.

In effect, when the earplug of this invention is inserted into the auditory canal, the flesh lining the auditory canal is compressed to a degree such that this flesh forms a thin and stiff mechanical junction between the envelope of the earplug and the bone structure of the ear itself. By the provision of the stiffening member the earplug may be easily inserted by applying a force along the longitudinal axis of the earplug. Since the outer envelope is elastic the inserting force will first cause a stretching of the front end of the earplug being inserted into the ear and therefore a pulling as well as a pushing of the earplug into the auditory canal. The provision of the commissure also provides means for retaining the earplug in the auditory canal since there will be a bulging of the cavities of 11 and 12 on either side of the commissure about the mouth of the auditory canal.

Reference should now be had to FIG. 11 which shows yet another earplug embodiment according to the invention.

At 91 there is shown a foamed material (e.g., plastic) stiffening member having one end thereof enlarged. The portion of the earplug housing the enlarged stiffening member portion is meant to be positioned outside the ear canal. The enlargement may be hollow (filled only with air), hollow and filled with a different type of foamed plastic having an open cell structure, or may be made of a continuous piece of the same open cell foamed plastic as the stiffening member shown in FIG. 7. The effect of this enlargement in one portion of the stiffening member is to increase the volume of air enclosed between the earplug and the tympanic membrane and therefore to decrease the change in air pressure in the ear canal caused by a given motion of the earplug. It has been found that if the foamed member is made sufficiently large, that is internally, to be able to contain about one cubic centimeter or more of air, substantial and appreciable improvement in attenuation of sound is achieved. It has also been found that it

is preferable to fill the enlargement 90 with an acoustic dampening material (e.g., foamed plastic such as polyurethane).

In the embodiment shown in FIG. 11, it is preferable to shield the enlarged portion of the stiffening member 91 from incident sound by means of a cap 92 (preferably metal or solid plastic [hard] preferably in the shape of substantially a half sphere. The cap is preferably formed with a center hole through which a static pressure leak is provided by means of a tube 93 opening into the interior air side of the earplug at one end and into the outer air through a puller handle 94 at the other end. Audible sound may be blocked in the static pressure leak by means of a grease or viscous liquid (e.g., silicone grease) stored in an enlarged portion 96 of the tube 93. The elastic envelope is shown at 97 and is preferably filled with a filler as heretofore described.

It will thus be seen that the objects set forth above among those made apparent in the preceding description are efficiently attained and that certain changes may be made in the above article without departing from the spirit and scope of the invention. It is intended that the matter contained in the above description and shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense. It is also to be understood that the following claims are intended to cover all generic and specific features of the invention herein described and all statements of the scope of the invention which as a matter of language might be said to fall therebetween.

I claim:

1. An earplug substantially in the shape of a dumbbell comprising a resilient and elastic envelope having first and second expansible hollow cavity portions at either end connected together through a commissure, a plastic filler material positioned within the envelope and having the property of slowly flowing between cavity portions through the commissure upon the squeezing of one of the cavity portions, said plastic filler material also being relatively unyielding to oscillatory acoustic pressures but slowly flowing under relatively sustained pressures so that one of the cavity portions may be compressed and remain so for a time sufficient to permit insertion into the ear canal of a user, one of said cavity portions expanding by acceptance after compression of the other of said cavity portions a more than initial amount of filler material therein and then slowly driving the filler material back through the commissure into the previously compressed cavity portion as the expanded cavity elastically attempts to return to its initial dimensions to expand the previously compressed cavity portion and a stiffening member which forms the major axis of the earplug and is coupled to the envelope portions forming said first and second cavity portions, said stiffening member being sufficiently stiff along its length to transmit an inserting force to insert the earplug into the ear canal.

2. An earplug according to claim 1 in which the stiffening member is at least in part surrounded by the en-

velope.

3. An earplug according to claim 2 in which the stiffening member is a tube.

4. An earplug according to claim 2 in which viscous liquid or grease is provided in the hollow portions of the tube to obstruct the passage of audible sound through said hollow tube while permitting an equalization of static air pressure at either end of said tube.

5. An earplug according to claim 1 in which the filler is a silicone putty.

6. An earplug according to claim 2 in which the stiffening member is a rod.

7. An earplug according to claim 2 in which the stiffening member is a tube or a rod and is constructed of a foamed plastic.

8. An earplug according to claim 1 in which the stiffening member includes bulging portions at either end thereof.

9. An earplug according to claim 1 in which the filler is a flowable plastic silicone compound.

10. An earplug for use by a user comprising a resilient and elastic envelope which assumes a dumbbell shape when unstressed, said envelope having an expansible hollow cavity portion at each end with a narrow connecting neck portion therebetween, an elongate stiffening member which extends axially through said neck and is coupled to said dumbbell shaped envelope substantially at each end thereof and a soft slowly flowing plastic filler material within said envelope, said plastic filler material being relatively unyielding to oscillatory acoustic pressures but flowing under sustained pressures so that one of said cavity portions which is to be inserted into the user's ear canal can be compressed, thereby displacing the corresponding portion of said plastic filler material through said neck portion and into the other elastic cavity portion which is constructed to expand outside of the user's ear canal under the pressure of said plastic filler material thereby permitting the compressed portion to be essentially pulled into the user's ear canal by said stiffening member and subsequently the elastic tension of the stretched envelope of the cavity portion outside of the ear canal will drive said plastic filler material back into the cavity portion within the ear canal, thereby establishing a substantial area of uniform compressive contact between that portion of the earplug and the interior of the user's ear canal.

11. An earplug according to claim 10 in which the filler material is a flowable plastic silicone compound.

12. An earplug according to claim 10 in which the stiffening member is a tube.

13. An earplug according to claim 11 in which the filler material is silicone putty.

14. An earplug according to claim 13 in which the cavity portions each have a diameter D_2 and wherein the neck portion has a diameter D_1 at its narrowest cross-section and wherein $D_1 = 0.5$ to $0.8 D_2$.

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