

Electric/acoustic transducer module, in-the-ear hearing aid and method for manufacturing an in-the-ear hearing aid

The present invention relates to an electric/acoustic transducer module for behind-the-ear or in-the-ear hearing aids as defined in the preamble of claim 1, also an in-the-ear hearing aid as defined in the preamble of claim 10 and a manufacturing method for such an in-the-ear hearing aid as defined in the preamble of claim 21.

In the case of hearing aids and, in particular, in-the-ear hearing aids, it is important that the loudspeaker housing is not connected to the auditory canal by a mechanically rigid bridge. This is important to prevent acoustic feedback from the loudspeaker to the input-side microphone as far as possible. Furthermore, where hearing aids are concerned, the space available is generally extremely limited and must be used optimally.

EP 0 548 580 discloses, for example, providing the electric/acoustic transducer arrangement on an in-the-ear hearing aid with a loudspeaker housing in which the motor-driven loudspeaker diaphragm and the motor driver for it are mounted. The diaphragm or the motor drivers for it are mounted in relation to said loudspeaker housing in such a way that the signals

induced acoustically by the diaphragm are transmitted directly to said housing. Said arrangement is fitted in an in-the-ear hearing-aid housing in such a way that the loudspeaker housing is as far away as possible from said hearing-aid housing, whereby only reduced acoustic transmission bridges are formed. As a result, however, assembly of the hitherto known hearing aids demands meticulous care that such bridges are not formed, i.e. a transducer arrangement must be inserted manually in the hearing-aid housing, as is also the customary practice, and meticulously aligned there.

The present invention has the aim of eliminating the disadvantages mentioned above. For this purpose, the electric/acoustic transducer module is distinguished by the characterizing features of claim 1.

Because the loudspeaker housing is resiliently mounted in the enclosure, it is possible for the transducer module to be installed in a behind-the-ear or in-the-ear hearing aid, whether in a form-fitting or frictionally locking manner. Furthermore, the, as mentioned, already necessary intermediate space between the loudspeaker housing and the hearing-aid housing is now exploited to acoustically improve the behavior of the hearing aid. This is achieved by the intermediate space provided by the invention at the transducer itself raising the bass range of the transducer module

by several dB, in that the intermediate space created by the invention enlarges by a multiple the chamber acoustically effective at the rear of the diaphragm as compared with this rear chamber in the loudspeaker housing itself. Reference can be made in this respect to US-A-3 257 516, where the advantages of large rear chambers are presented.

In a preferred embodiment, the enclosure acts as a magnetic shield and, for this purpose, is preferably made of μ metal. Very simple assembly and disassembly of the transducer arrangement, in particular the insertion of the loudspeaker housing with loudspeaker, is achieved by the enclosure comprising a cup-shaped part. This is preferably metallic. In a further preferred embodiment, - following insertion of the loudspeaker housing with loudspeaker - said cup-shaped part is closed by means of a cover element which has the acoustic output of the transducer arrangement. In an embodiment preferred by far, said cover element comprises as the acoustic output an aperture at which the first chamber on one side of the loudspeaker diaphragm, that is to say that chamber which is coupled to the acoustic output of the transducer arrangement, is separated from the ambience by means of a membrane. The membrane lies in an unhampered manner across the aperture. In a further embodiment, the cup is completed by a hose-like

elastomeric cover. Both designs practically achieve a sealing of the interior of the transducer module, which is highly desirable in view of the soiling of acoustically important transmission elements, known in particular in the case of in-the-ear hearing aids. Consequently, it is readily possible to clean the transducer module with respect to soiling of this kind. Neither dirt nor moisture can enter the module.

The membrane provided according to the invention in the preferred embodiment mentioned differs from that presented and described for example in the aforementioned EP 0 548 580 by being installed in a freely vibrating manner and not motor-driven. By dimensioning the acoustically effective chambers provided according to the invention and the membrane characteristics in a way customary to a person skilled in the art, with impedance matching in mind, the effect is achieved that said membrane scarcely affects the acoustic transmission behavior of the hearing aid on the output side of the loudspeaker.

In a particularly preferred embodiment, at least the free part of the membrane is in this case made homogeneously in terms of its material, i.e. from one material phase, and, in a further preferred feature, is of a constant thickness. Consequently, said membrane is of an extremely simple structural design and the acoustic behavior of the membrane is

straightforward.

In a preferred embodiment, at least the free part of said membrane is in this case of elastomeric material, such as for example latex or silicone rubber, extremely low-cost materials that are produced with a uniform, small thickness, resistant and unobjectionable with respect to how they behave in contact with living tissue. The membrane is preferably airtight. Its thickness is preferably $d \leq 0.09$ mm.

Furthermore, to allow the loudspeaker housing to be installed as simply as possible into the enclosure while taking into account the acoustic decoupling between the loudspeaker housing and the enclosure, it is further proposed that the loudspeaker housing is fixed in the enclosure by means of flexible bearing blocks. Furthermore, to optimally exploit said intermediate space, it is further proposed in a preferred embodiment that the loudspeaker housing is enclosed on all sides by said intermediate space apart from bearing locations of the loudspeaker housing on the enclosure.

The in-the-ear hearing aid according to the invention has an electric/acoustic transducer arrangement of the type described above. The potential for simple assembly is fully exploited in that the enclosure of the transducer module is positioned in the hearing-aid housing in a form-fitting and/or

frictionally locking manner.

As a result, and as still to be mentioned, this creates the basis for producing such hearing aids in an automated manner: the avoidance of acoustic bridges between the loudspeaker housing and the housing of the hearing aid is solved a priori by installing the transducer module according to the invention.

At the same time, in a preferred embodiment of the hearing aid according to the invention, the acoustic output of the transducer module can be connected to the acoustic output aperture of the hearing-aid housing, again in a customary way, by means of a tubular stub.

In a further preferred embodiment of the in-the-ear hearing aid according to the invention, in any event a membrane fixed in such a way as to allow free, unhampered vibration is provided, separating the ambience of the hearing aid from the first chamber at the transducer module used according to the invention.

This membrane may obviously be formed by the previously mentioned membrane on the transducer arrangement according to the invention itself, though this is not mandatory and the preferred embodiments [sic] made in this respect above apply in all cases.

In a further preferred embodiment, however, said membrane is mounted directly in the region of the acoustic output of the hearing aid. This prevents any

soiling at all from entering not only the transducer module but also the transducer input at the hearing aid itself.

In a further preferred embodiment of the hearing aid according to the invention, the acoustic output of the transducer module according to the invention is therefore provided essentially directly at the output aperture of the hearing-aid housing, whereby said membrane, if provided in the preferred way, is provided directly in the ambience of the hearing-aid housing on the one hand and directly at the output of the transducer module on the other hand. As a result - as mentioned - on the one hand this solves the problem concerning the trapping of dirt at an output aperture provided at the hearing aid by said aperture being closed directly by said membrane, on the other hand it provides the possibility of optimizing the acoustic behavior in the sense that no additional intermediate transmission paths have to be provided from the acoustic output of the transducer module to the acoustic output of the hearing aid. The remaining acoustic transmission path can be provided solely on the basis of acoustic impedance matching.

In an embodiment of the hearing aid most especially preferred in terms of design, the acoustic output aperture of the hearing-aid housing is formed by an element connected in a plate-like manner to the

remaining hearing-aid housing, for example welded or adhesively bonded. It is preferably proposed in the case of this embodiment as well that said output aperture is closed by means of a membrane, which however is now preferably formed integrally with said element. The comments mentioned above also apply with respect to this membrane, which means that said element preferably consists of elastomeric material, for example of latex or silicone rubber.

The method according to the invention for manufacturing a hearing aid, in particular an in-the-ear hearing aid according to the invention, is distinguished by the fact that the transducer module is positioned in the hearing-aid housing in a form-fitting or frictionally locking manner. This makes it possible with little effort for the transducer module to be positioned in the hearing-aid housing exactly in place or even to be pressed in a frictionally locking manner between elements of the hearing-aid housing or, for example, for the transducer module to be cast with the hearing-aid housing.

As a result, the preferred embodiment of said method is made possible, that is of inserting the transducer module into the hearing-aid housing in an automated manner.

In a further preferred embodiment, the transducer module is then inserted into the hearing-aid

housing through an aperture forming the acoustic output of the hearing-aid housing, that is to say from below. This provides the basis for a further preferred approach, that is that the transducer module is positioned into a receiving aperture of a support plate and, by means of relative movement of the support plate and the hearing-aid housing, the transducer module is inserted into the hearing-aid housing from the end forming the acoustic output of the hearing-aid housing. The automation procedure made feasible in this way is quite clear to a person skilled in the art: the appropriate number of transducer modules are positioned into a multiplicity of receiving apertures in said support plate and said modules are pushed from below into a corresponding number of hearing-aid housings of in-the-ear hearing aids to be manufactured.

In a further preferred embodiment, the support plate is subsequently used as part of the hearing-aid housing by being connected to the hearing-aid housing, preferably adhesively bonded or welded, and then the support plate is trimmed off along the outside contour of the hearing-aid housing.

In a further preferred embodiment of the method according to the invention, the receiving aperture for the transducer module on the support plate is formed as a blind aperture, providing the possibility, in a further preferred embodiment, of forming the base

element of the blind aperture as the abovementioned membrane, integrally with the support plate, or mounted on the support plate as a sheet-like structure. If the cover of the blind aperture is used as a membrane in the sense referred to above and is integral with the support plate, the support plate will, as is clearly evident, be produced from material which meets the requirements for the material of the membrane, that is to say preferably from elastomeric material, in this case for example from latex or silicone rubber.

The invention is explained below by way of example on the basis of figures, in which:

figure 1 shows the diagram of a transducer module according to the invention;

figure 2 shows in a diagrammatically simplifying form a longitudinal section through a transducer module according to the invention;

figure 2a shows a diagrammatic representation of a further preferred embodiment of the transducer module according to the invention;

figure 3 shows, again diagrammatically, the installation of a transducer module according to the invention on an in-the-ear hearing aid;

figure 4 shows in a representation analogous to that of figure 3 a further possible way of installing a transducer module according to the invention on an in-the-ear hearing aid;

figure 5 shows in a representation analogous to Figures 3 and 4a further preferred design variant of the element forming the acoustic hearing-aid output of an in-the-ear hearing aid, and

figures 6(a) to 6(c) diagrammatically show the sequence of a manufacturing method for an in-the-ear hearing aid with regard to assembling the electric/acoustic transducer module and the hearing-aid housing.

Figure 1 diagrammatically shows a transducer module for explaining the acoustic coupling principles.

The transducer module 1 comprises a loudspeaker housing 3, in which the loudspeaker diaphragm 5 is mounted. The loudspeaker diaphragm 5 is excited by a motor drive 7, which is only diagrammatically represented. In the loudspeaker housing 3, a front chamber R_1 and a rear chamber R_2 are formed by the loudspeaker diaphragm 5. One of the two said chambers, for example the rear chamber R_2 , is acoustically coupled by acoustic coupling apertures 9 to an intermediate space 11, formed between the loudspeaker housing 3 and an enclosure 13. The enclosure 13, and consequently the intermediate space 11, surround the loudspeaker housing 3 essentially entirely, apart from resilient bearing elements 15, by means of which the loudspeaker housing is kept at a distance, mounted essentially in a "floating" manner, within the enclosure 13. According

to figure 1, the front chamber R_1 is connected to the acoustic output A_A of the transducer module 1.

With the design shown, an acoustic decoupling of the effect of the loudspeaker on the enclosure 13 is achieved on account of the essentially floating mounting of the loudspeaker housing 3. Furthermore, by significantly enlarging the rear diaphragm chamber R_2 , that is including the intermediate space 11, the acoustic behavior of the transducer module 1 is significantly improved as compared with that of the loudspeaker arrangement in the housing 3: the bass response of the transducer module is raised by several dB as compared with the bass response of the loudspeaker arrangement in the housing 3.

In a preferred embodiment of the transducer module 1, a membrane is provided at the acoustic output A_A of this module itself, as diagrammatically represented by 17. Apart from being fixed at its edge, the membrane 17 vibrates freely. It preferably consists of a homogeneous material phase, preferably an elastomeric material, for example latex or silicone rubber, and, in a further preferred feature, has a constant thickness of about 100 μm , preferably at most 0.09 mm.

By matching the acoustic impedance of the intermediate space 11 with the chamber R_2 , the chamber R_1 as far as the membrane 17, the membrane 17 and any

acoustic conductor that might be provided to propagate toward the ambience U of the transducer module 1, the effect is achieved that the membrane 17 is practically acoustically transparent.

Figure 2 shows a cross section through an embodiment of the transducer module 1. The reference symbols already used in the diagrammatic representation of figure 1 are also used here. The loudspeaker housing 3 with the coupling apertures 9 is mounted on the enclosure 13 by means of elastomeric bearing blocks 19. The enclosure 13 is formed by a cup 20, which preferably acts at the same time as a magnetic shield and, for this purpose, preferably consists of μ metal.

In any event, the cup 20 is preferably metallic. The cup 20 is closed by a cover part 22. The membrane 17, already presented in figure 1, may in this case be mounted directly on the cover part 22. At the same time, the cover part 22 and the membrane 17 may well be integrally formed, in which case however the material of the cover part 22 must meet the material requirements for the membrane, for instance with respect to elastomeric behavior. For example, the entire part 22 is then made of latex or silicone rubber. Otherwise, however, the membrane 17 is anchored as a separate part on the cover part 22. The membrane 17 may also be provided between the acoustic output A₁ in the loudspeaker housing 3 and the clear

aperture in the part 22. Preferably, however, as represented in figure 2, the membrane 17 is provided flush with the clear aperture in the cover part 22, whereby the complete transducer module 1 appears as a self-contained, encapsulated unit and can be readily cleaned. This is especially significant if, as still to be shown, the output A_1 of the transducer module 1 lies directly at the acoustic output of a hearing aid.

The transducer module or its enclosure 13 may be cubic, cylindrical or designed in some other form of essentially any desired kind, provided that the required intermediate space 11, essentially enclosing the loudspeaker housing 3, is formed between the loudspeaker housing 3 and the enclosure 13. On the basis of the explanations relating to figure 2, figure 2a shows a further embodiment in a merely diagrammatic form. Here, an elastomeric hose 17a is pulled over the enclosure 13. Said hose 17 at the same time forms the cover part 22 and membrane 17.

Figure 3 diagrammatically shows the segment of an in-the-ear hearing aid 24 with the acoustic output aperture A_2 . The transducer module 1, designed as shown in figures 1, 2 and 2a, is installed within the hearing-aid housing 26, to be precise in that it is secured and positioned in the housing 26 of the hearing aid in a form-fitting or frictionally locking manner, as diagrammatically represented by the securing and

positioning clips 28 in figure 3. This is made possible by the acoustic decoupling of the outer enclosure 13 with respect to the loudspeaker housing 3 provided on the transducer module explained with reference to figures 1, 2 and 2a.

Apart from this, the design of the in-the-ear hearing aid shown in figure 3 is essentially as already known, in that the acoustic output of the transducer module 1 is connected to the acoustic output aperture A_2 of the hearing aid via an tubular stub 30.

The electronic components and the input-side acoustic/electric transducer arrangement on the in-the-ear hearing aid 24 with the housing 26 are not represented in figure 3 and the further figures because they are not essential for the invention.

As figure 3 further shows, the membrane 17 provided in the preferred embodiment is installed in the direct region of the acoustic output A_2 on the hearing-aid housing 26.

According to figure 4, the transducer module 1 is fitted in a form-fitting or frictionally locking manner directly in the region of the acoustic output A_2 of the hearing aid 24 or of the housing 26, as represented by the diagrammatically shown securing means 28a. In a preferred embodiment, the freely vibrating membrane 17 is provided at the end.

According to figure 5, the housing 26 of the

in-the-ear hearing aid 24 is formed on the one hand by a main housing part 24a, but at the end a cover part 24b is placed in a plate-like manner on the part 24a, glued or welded to the part 24a. A transducer module 1 as described in relation to figures 1 and 2, or directly the loudspeaker housing of a hitherto known loudspeaker arrangement, in figure 5 both denoted together by 30, is seated in the output aperture 32 of the cover part 24b and is secured there, such as by clamping, gluing etc. If the transducer module represented in a general manner by 30 in figure 5 is one with an enclosure, i.e. is designed in the manner of figures 1, 2 or 2a, positioning and fixing members may be provided for this transducer module 1 within the hearing-aid housing 26, as in turn diagrammatically indicated by 28.

The membrane of the type described above, or a preferably provided membrane, is also represented by 17 in figure 5, in a preferred position. As still to become evident, the design according to figure 5 has major advantages, whether for hearing aids with a transducer module according to figures 1, 2, 2a or for hearing aids with a hitherto known transducer arrangement, i.e. with a loudspeaker housing directly on the outside. Furthermore, the membrane 17 may be integrally formed with the part 24b, in particular because, with the part 24b separate from the rest of

the housing 26, the choice of material for this part can be matched to the requirements of the membrane 17.

Figures 6(a) to 6(c) diagrammatically show the sequence of a preferred manufacturing method for in-the-ear hearing aids.

According to figure 6(a), receiving apertures 36, preferably in the form of blind apertures, are provided in a support plate 34 and the transducer arrangements 30 to be provided on in-the-ear hearing aids are inserted in said apertures. If the transducer arrangements 30 are of a known type, i.e. with an external loudspeaker housing and without an enclosure according to figures 1, 2, 2a, the transducer arrangements 30 are preferably firmly anchored in the support plate 34, for instance are adhesively bonded to it. If, however, they are transducer arrangements with an external enclosure according to figures 1, 2, 2a, the arrangements 30 need not be firmly secured in the support plate 34, because they can, as has been shown, be secured in the corresponding hearing-aid housings 24a in a form-fitting or frictionally locking manner, as indicated with dashed lines by 28b. Of significance with regard to the technical aspects of the method is firstly that, due to relative movement of the plate 34 with the transducer arrangements 30 and a corresponding number of housing parts 24a, the transducer arrangements 30 are not pushed in the customary manner

from above, but from below, into the elements of the housing parts 24a facing the acoustic output.

In the case in which the transducer arrangements 30 are designed with enclosures, once the transducer systems 30 have been pushed into the housings 26 in a securing manner, the support plate 34 can be removed, the transducer arrangements or modules being secured and positioned in the housings 24a. However, in the case concerning transducer arrangements without enclosures, the transducers 30 remain in the apertures 36 of the plate 34 provided for them. The plate 34 is connected, for example adhesively bonded or welded, to the housing 24a and, based on the position according to figure 6(b), the plate 34 is subsequently trimmed to become flush with the outer housing contour (transition to figure 6(c)).

This produces the in-the-ear hearing aid as represented in figure 5. However, this procedure is also used with preference for transducer modules designed according to figures 1, 2, 2a, i.e. with enclosures.

It is thus evident from viewing figure 6 that this procedure is extremely well-suited for installing the membrane 17, or a further membrane preferably to be provided, at the same time as a guard to protect the acoustic hearing-aid output from soiling and to ensure simple cleaning. For this purpose, the base plate 38

according to figure 6(a) of the preferred apertures 36, preferably formed as blind apertures, is formed directly as the membrane. This takes place by either the material of the support plate 34 being chosen to meet the requirements for the membrane material, and consequently the membrane being formed integrally with the plate 34, or, as represented by dashed lines in figure 6(a), by the blind apertures 36 being formed by laminating the support plate 34, the apertures 36 still being open right through, with a sheet-like layer 34b which then forms the membrane 17 according to figure 5.

The production method represented makes it possible to fit both transducer modules according to figures 1, 2, 2a and conventional transducer arrangements, i.e. with an external loudspeaker housing, in the in-the-ear hearing-aid housing without meticulous positioning manipulations. This can be carried out from that side of the housing on which the acoustic output lies. Consequently, assembling of a kind which can be automated to the greatest extent is made possible. If, as preferred, the acoustic output of the hearing aid is to be designed such that it is protected against soiling from the ambience and allows good cleaning, this at the same time provides the possibility, as explained, of also installing a covering membrane 17.

**Patent claims:**

1. Electric/acoustic transducer module for behind-the-ear or in-the-ear hearing aids with at least one loudspeaker with a diaphragm driven by an electric motor in a loudspeaker housing, characterized in that the loudspeaker housing is resiliently mounted in an enclosure which, together with the loudspeaker housing, forms an intermediate space, with a first chamber in the loudspeaker housing, on one side of the loudspeaker diaphragm, being coupled to the acoustic output of the transducer arrangement, and a second chamber in the loudspeaker housing, on the other side of the diaphragm, being coupled to the intermediate space.
2. Transducer module according to claim 1, characterized in that the enclosure acts as a magnetic shield and, for this purpose, is preferably produced from μ metal.
3. Transducer module according to either of claims 1 and 2, characterized in that the enclosure comprises a cup-shaped part, preferably a metallic part.
4. Transducer module according to claim 3, characterized in that the cup-shaped part has a cover element with the acoustic output.
5. Transducer module according to claim 4, characterized in that the cover element has an aperture at which the first chamber is separated from the



ambience by a membrane, the membrane lying in an unhampered manner across the aperture, or in that the cover element is formed by an elastomeric hose forming the membrane.

6. Transducer module according to claim 5, characterized in that at least the free part of the membrane is homogeneous in terms of its material and preferably has a constant thickness, preferably of at most 0.09 mm, in that, in a further preferred feature, the membrane closes the module in an airtight manner.

7. Transducer module according to claim 5, characterized in that at least the free part of the membrane consists of elastomeric material.

8. Transducer module according to one of claims 1 to 7, characterized in that the loudspeaker housing is fixed in the enclosure by means of flexible bearing blocks.

9. Transducer module according to one of claims 1 to 8, characterized in that the intermediate space encloses the loudspeaker housing essentially on all sides, apart from bearing locations of the loudspeaker housing on the enclosure.

10. In-the-ear hearing aid with a hearing-aid housing which on one side has an acoustic output aperture and with an electric/acoustic transducer arrangement, characterized in that the electric/acoustic transducer arrangement is designed as



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a module according to one of claims 1 to 9.

11. Hearing aid according to claim 10, characterized in that the enclosure of the transducer module is positioned in the hearing-aid housing in a form-fitting and/or frictionally locking manner.

12. Hearing aid according to either of claims 10 and 11, characterized in that the acoustic output of the transducer module is connected to the acoustic output aperture of the hearing-aid housing by means of a tubular stub.

13. Hearing aid according to one of claims 10 to 12, characterized in that a membrane fixed in such a way as to allow free, unhampered vibration separates the ambience of the hearing aid from the first chamber, preferably in an airtight manner.

14. Hearing aid according to claim 13, characterized in that at least the free part of the membrane is homogeneous in terms of its material and preferably has a constant thickness, preferably of at most 0.09 mm.

15. Hearing aid according to claim 13, characterized in that at least the free part of the membrane consists of elastomeric material.

16. Hearing aid according to claim 13, characterized in that the membrane is mounted on the transducer module and/or the hearing-aid housing.

17. Hearing aid according to one of claims 10 to



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16, characterized in that the acoustic output of the transducer module is arranged essentially in or at the output aperture of the hearing-aid housing.

18. Hearing aid according to one of claims 10 to 17, characterized in that the acoustic output aperture of the hearing-aid housing is formed by an element connected in a plate-like form to the remaining hearing-aid housing, for example welded or adhesively bonded.

19. Hearing aid according to claim 17, characterized in that a membrane closing the output aperture is formed integrally with the element.

20. Hearing aid according to claim 19, characterized in that the element consists of elastomeric material.

21. Method for manufacturing a hearing aid, in particular an in-the-ear hearing aid according to one of claims 10 to 19, characterized in that the transducer module according to one of claims 1 to 9 is positioned in the hearing-aid housing in a form-fitting or frictionally locking manner.

22. Method according to claim 21, characterized in that the transducer module is inserted into the hearing-aid housing in an automated manner.

23. Method according to either of claims 21 and 22, characterized in that the transducer module is inserted into the hearing-aid housing through an aperture



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forming the acoustic output of the hearing-aid housing.

24. Method according to claim 23, characterized in that the transducer module is fitted into a receiving aperture of a support plate and, by means of relative movement of the support plate and the hearing-aid housing, the transducer module is inserted into the hearing-aid housing from the end forming the acoustic output of the hearing-aid housing.

25. Method according to claim 24, characterized in that the support plate is connected to the hearing-aid housing, preferably adhesively bonded or welded, and then the support plate is trimmed off along the contour of the hearing-aid housing.

26. Method according to claim 25, characterized in that the receiving aperture for the transducer module on the support plate is formed as a blind aperture.

27. Method according to claim 26, characterized in that the base plate of the blind aperture is formed as a membrane integrally with the support plate or mounted on the support plate as a sheet-like structure.