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(72) Galley, Geoffrey Harrison, GB
(73) Galley, Geoffrey Harrison, GB

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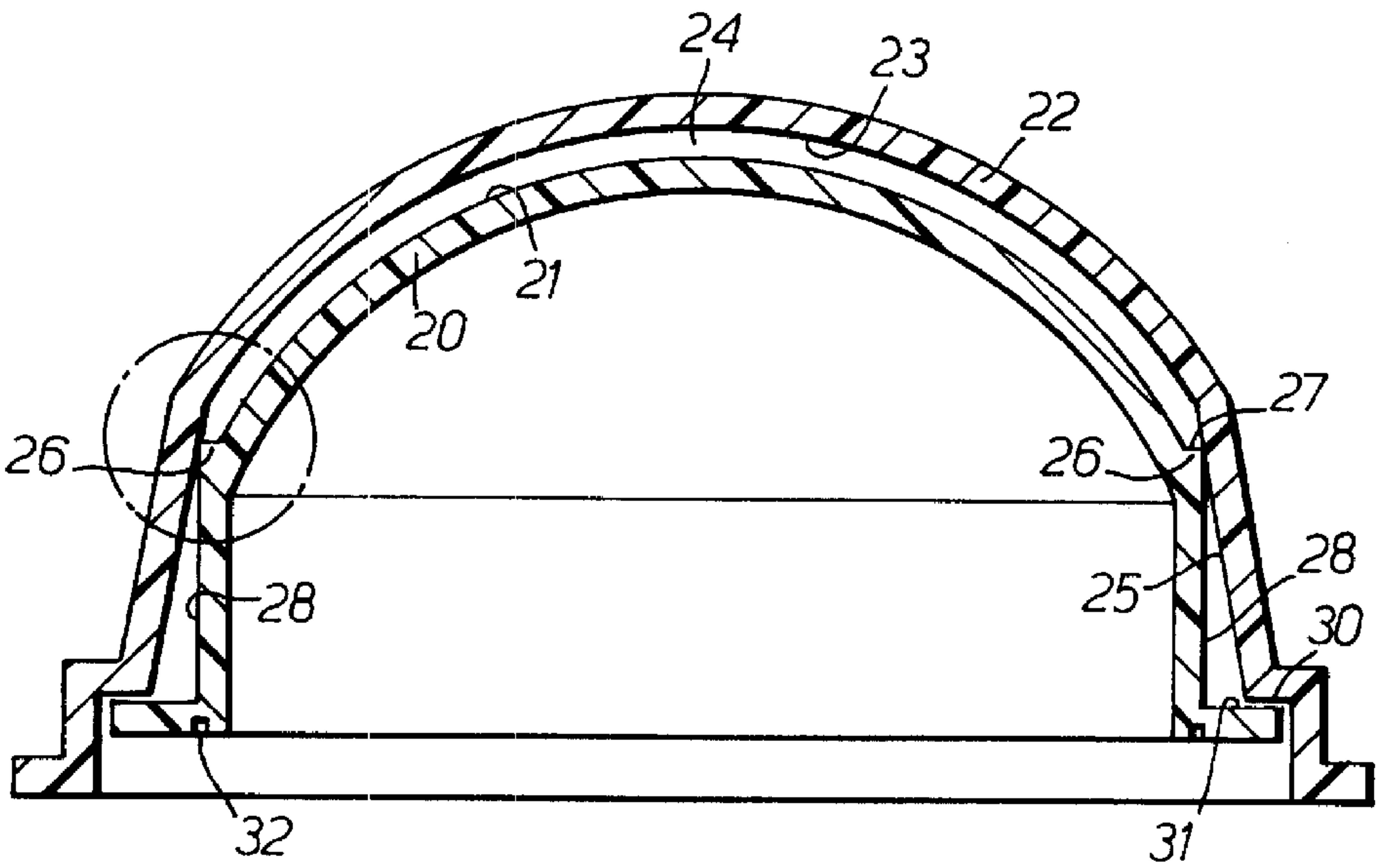
(54) **MOULES POUR LA FABRICATION DE VERRES DE CONTACT**

(54) **CONTACT LENS MANUFACTURE AND MOULDS**



(57) A plastics material mould for casting a contact lens from curable material comprises disposable male a.nd female mould members (20,22;50,51) defining a mould cavity and each having a curved surface (21,23;52,54) for moulding a respective optical surface of the contact lens, the male mould member having a shoulder (26,53) which is a slidable fit with a generally cylindrical, e.g. frusto-conical, surface (25,55) on the female mould member to permit relative mould member movement during curing without substantially affecting the optical quality of the moulded optical surfaces. The sliding fit shoulder and female surface are relatively simple to mould with accuracy and thus permit the edge (29) of the eventual cast lens to be formed relatively reliably and accurately.

CONTACT LENS MANUFACTURE AND MOULDS

ABSTRACT

A plastics material mould for casting a contact lens from curable material comprises disposable male and female mould members (20,22;50,51) defining a mould cavity and each having a curved surface (21,23;52,54) for moulding a respective optical surface of the contact lens, the male mould member having a shoulder (26,53) which is a slidable fit with a generally cylindrical, e.g. frusto-conical, surface (25,55) on the female mould member to permit relative mould member movement during curing without substantially affecting the optical quality of the moulded optical surfaces. The sliding fit shoulder and female surface are relatively simple to mould with accuracy and thus permit the edge (29) of the eventual cast lens to be formed relatively reliably and accurately.

CONTACT LENS MANUFACTURE AND MOULDS

This invention relates to the manufacture of contact lenses by cast moulding technology, and in particular to disposable plastics material moulds for casting contact lenses.

Contact lenses are traditionally manufactured by several means including "lathing", "spin casting" and "cast moulding" Each of the above methods possesses advantages in terms of the cost of production of lenses or the variety of lens designs and materials which may be produced. Cast moulding offers significant advantages in respect of relatively low cost of capital plant employed in the production process as well as low unit cost of production while being utilisable over a wide range of polymeric materials.

Present methods of cast moulding described in U.S. Patent No. 4,208,364 (Shepherd) and U.S. Patent No. 4,284,399 (assigned to American Optical Corporation) suffer in practice from relatively low production yields due to defects in or originating from the edge of the cast lens, and in the case of the method described in U.S. Patent No. 4,209,289 (assigned to American Optical Corporation), from numerous instances of poor optical quality.

U.S. 4,208,364 (Shepherd) teaches the casting of a lens between two disposable plastic mould members one of which is provided with a deformable lip which facilitates the relative movement of the mould members towards each other in order to compensate for the shrinkage of the lens polymer which occurs during polymerisation. Said movement maintains contact between the optical surfaces of the mould members and the lens polymer thus ensuring good optical quality of the lens. However, said deformable lip against which the edge of the lens is formed, being of a disadvantageous cross-sectional form and minute dimensions, is difficult to produce to the required degree of precision by the specified injection moulding process.

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The resulting lens edges frequently exhibit imperfections which may become more pronounced during the process of removing the formed lens from the assembled mould members. Such imperfections existing in the edge of the lens often cause the lens to be judged as unfit for use. In addition, such imperfections often form sites for the initiation of cracks which may propagate into the lens providing further cause for rejection of the lens on inspection.

A further limitation of the method taught in the Shepherd patent results from variable deformation of the described flexible lip which in turn results in variation of the edge thickness around the lens and, at times, in unacceptable variation in the lens centre thickness.

As a result of the above deficiencies, the production yield of lenses manufactured by the Shepherd method, being the number of lenses produced from a given number of cast mouldings, is generally of the order of 50% or less.

The method described in U.S. Patent No. 4,284,399 (assigned to American Optical Corporation) does not provide a means for the mould members to move towards each other during polymerisation other than by deformation of the surfaces of the mould members, which appears to be assisted by the loading of the assembled members with a weight of "two to three pounds". The deformation of the surfaces of the mould members can be expected to result in loss of optical quality in the moulded lens.

The method can further suffer from imperfections in the lens edge which is formed against the junction line between the two mould members. Misalignment of the mould members on assembly of the members prior to polymerisation of the lens forming monomer may occur due to variation in the actual size of the mould members produced from given tooling at different times. Any such misalignment will result in a deformation of the lens edge.

A further limitation of the method described in the American Optical patent lies in the fact that the configuration of the portion of the female mould member at the point where the edge is formed against such member, being of disadvantageous cross-sectional form and minute dimensions, does not lend itself to production by the injection moulding process specified in the patent. The lens edge form shown in the patent could not therefore be effectively moulded without deformation resulting from imperfections in the said portion of the female mould member.

It is an object of the present invention to overcome the described edge-related problems by providing a mould and a method which will result in an acceptable edge form while at the same time providing a means for the mould members to move towards each other in order to compensate for shrinkage which occurs during the polymerisation of the lens forming monomer.

A further object of the invention is to provide a configuration for the respective mould members which can be readily moulded by a conventional injection moulding process such that the lens edge form described may be reliably achieved utilizing the said mould members.

According to the present invention there is provided a plastics material mould for casting a contact lens from curable material, said mould comprising:

male and female mould members adapted to fit together to define a mould cavity; and

said male and female mould members each present a curved surface for moulding a respective desired optical surface of a contact lens;

characterized in that

said male mould member has a shoulder surrounding its optical curved surface;

said female mould member presents a generally cylindrical surface surrounding its optical curved surface; and

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said shoulder is a slidable fit with said generally cylindrical surface when the mould members are assembled to permit the mould members to move relative to one another during curing of said curable material introduced into the mould cavity to cast a lens.

In another aspect the invention provides a method of casting a contact lens from curable material characterized by the steps of:

providing disposable male and female mould members which fit together to define a mould cavity and each present a curved surface for moulding a respective desired optical surface of the contact lens, the male mould member having a shoulder surrounding its optical curved surface, and the female mould member presenting a generally cylindrical surface surrounding its optical curved surface;

charging the female mould member with a predetermined dose of monomeric material;

assembling the charged female member with the male member with the shoulder being an engaging slidable fit with the generally cylindrical surface;

curing the monomeric material while permitting the mould members to move relative to one another with the shoulder in sliding engagement with the generally cylindrical surface; and

removing the cast lens from the mould members.

The embodiments of the invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1a is a vertical section through the prior art Shepherd mould;

Figure 1b is an enlarged fragmentary view of an edge portion of the Shepherd mould;

Figure 2a is a vertical section through the prior art American Optical mould;

Figure 2b is an enlarged fragmentary view of an idealized edge portion in that mould;

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Figure 2c is an enlarged fragmentary view of an actual edge portion of that mould;

Figure 3a is a vertical section through a mould according to the present invention;

Figure 3b is an enlarged fragmentary view of an edge portion of the mould of Figure 3a;

Figure 4 is a vertical section through a second embodiment of a mould according to the invention adapted for mounting on a lathing machine; and

Figure 5 is a vertical section through a third embodiment of a mould according to the present invention.

Figures 1a and 1b show the prior art Shepherd mould having male and female mould members 10,11 the male member having a deformable lip 12. The practical disadvantages of this arrangement have been described above, in particular that the deformable lip 12, against which the edge of the lens is formed, is of disadvantageous cross-sectional form and minute dimensions.

Figures 2a to 2c show the prior art American Optical mould having male and female mould members 15,16 provided with abutting annular seats 17,18. The practical disadvantages of this arrangement have been described above, in particular that the seats 17,18 do not provide means for the mould members to move towards each other during polymerisation other than by deformation of the mould members. In addition the seat portion 18 of the female member, against which the edge of the lens is formed, is again of disadvantageous cross-sectional form and minute dimensions. While Figure 2b shows an idealised shape, in practice the shape tends to be variable and more as shown in Figure 2c.

Figures 3a and 3b show an embodiment of the present invention. A mould member 20 having a convex optical surface 21 is generally referred to as the male mould member and the base curve of the cast contact lens is formed against the optical surface 21. A mould member 22 having a concave optical surface 23 is generally referred to as the female mould member and the anterior surface of the cast contact lens is formed against the optical surface 23. The male and female mould members fit together to define a mould cavity 24 within which the lens is cast.

The mould members 20,22 may conveniently be manufactured by an injection moulding process using a thermo-moulding polymer such as poly-propylene.

The female mould member 22 is provided with a generally cylindrical surface 25 which may be a right circular cylindrical surface or which may advantageously be of a frusto-conical form (as shown in Figs. 3a and 3b) so as to provide a lead-in for the opposing shoulder of the male mould member 20 which mates with the said cylindrical surface 25 of the female mould member upon assembly of the mould members prior to polymerisation of the lens monomer. The male mould member is provided with a shoulder 26 surrounding its optical curved surface 21. The shoulder presents a substantially right-angled corner formed by the junction of a first annular surface 27 facing the female mould member and a second right circular cylindrical surface 28.

The female mould member 22 is assembled with the male mould member 20 after first being charged with a metered dose of monomeric material from which the contact lens will be formed by polymerisation. Polymerisation of the monomeric material is then effected by heating the assembly ir a waterbath or temperature-controlled oven or by other means familiar to those skilled in the art such as ultra-violet radiation in which case at least one of the mould members must be formed from a material which is transparent or semi-transparent to such radiation.

The edge 29 of the lens is formed between the surface 27 of the shoulder 26 of the male mould and a portion of the cylindrical or frusto-conical surface 25 of the female mould as shown in Fig. 3b. The engagement of the corner at the junction between the surfaces 27 and 28 of the shoulder of the male mould member against the surface 25 of the female mould member provides a running

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seal between the two members through which excess monomeric material may escape from the cavity contained between the two mould members during the progressive assembly of the members.

During polymerisation of the monomeric lens-forming material the male and female mould members may approach each other as the corner junction of surfaces 27 and 28 of the shoulder of the male mould member slides along the surface 25 of the female mould member. The positioning of the male mould member relative to the female mould member upon assembly of the members may be determined by appropriate adjustment of the stroke of the assembling means provided on a machine within or upon which the mould members are assembled.

Alternatively the mould members may be provided with mating flat ring surfaces respectively marked as 30 and 31 in Fig. 3a. In this case a hinging effect which occurs at the intersection of the surfaces 31 and 27 of the male mould member permits the surfaces of the mould members to move towards each other by means of the above described sliding of the shoulder of the male mould member along the cylindrical or frusto-conical surface of the female mould member. The male mould member may if required be weakened as shown at 32 by reduction of the wall thickness in the region of the point of intersection of the surfaces 31 and 27 so as to facilitate the above described hinging effect.

It will be noted that it is not necessary to place any load on the assembly during the polymerisation process. The shrinkage of the monomeric material during polymerisation serves to draw the two optical surfaces together by a combination of atmospheric pressure and adhesion of the respective surfaces of the mould members to the polymerising monomeric material. The above described sliding fit between the surface 25 of the female mould member and the opposing shoulder 26 of the male mould member coupled with the hinging effect between surfaces 27 and 31 of the male mould member minimises the resistance to movement of the mould members towards each other under the influence of atmospheric pressure and or adhesive attachment of the respective surfaces of the mould members to the polymerising monomeric material.

Fig. 3b is an enlarged view of the mould members in the region where the lens edge 29 is formed between the mould members. From this it will be seen that the configuration of each of the mould members in this region is such as to be readily mouldable using conventional injection moulding technology. Narrow and acutely angled cross-sections such as may be found in the region of the lip 12 on the relevant mould member of Shepherd or in the extreme edge 18 of the female mould member of American Optical have been avoided. Both mould members of the present embodiment have relevant cross-sections consisting of right angles or obtuse angles which may be accurately reproduced by conventional injection moulding techniques.

As shown in Fig. 4, the disposable mould members may advantageously be designed incorporating a means 40 for mounting the mould members in their assembled form onto the rotating spindle 41 of a lathing machine (not shown) which may have cutting tool 42 to remove a portion 43 of the female mould member from the assembly so as to expose the front surface and a portion of the edge of the cast lens 44. After removal of the female mould portion 43 the lens 44 may be easily released from the male mould by distortion of the mould surface which may be achieved by a simple squeezing action applied at the base of the mould assembly.

In another embodiment (not shown) the portion of the female mould may be removed with the lens adhering to such portion from which it may subsequently be detached by a squeezing action applied across the diameter of the removed female mould portion.

The removal of the female mould portion as above described may be advantageously performed on a special purpose machine (not shown) wherein the loading of the mould assembly onto the rotating spindle and the machining of the portion of the female mould are carried out automatically.

The lens edge produced by the above described moulds and methods is of an essentially triangular cross-section with its apex occurring at the approximate mid point of the edge. If a different cross-sectional edge profile is required the moulded edge may be polished by conventional lens edge polishing means or by tumbling the lens utilizing small glass spheres in a manner similar to that used during the production of intra-ocular lenses.

Figure 5 shows a further embodiment comprising a male mould member 50 and a female mould member 51. The male mould has a convex optical surface 52 and a shoulder 53 similar to shoulder 26 described in relation to Figures 3a and 3b. The female mould has a generally cylindrical surface surrounding its concave optical surface 54. The generally cylindrical surface comprises first, second and third surfaces in succession away from the optical surface 54. The first surface is a frusto-conical surface 55 tapering outwardly at a taper angle preferably in the range of from 5 to 10°, for providing the slidable fit with the shoulder 53 of the male member as described in relation to Figure 3a and 3b. The second surface is substantially a right circular cylindrical surface 56 to improve seating of the mould members together upon assembly. The third surface is a frusto-conical surface 57 tapering outwardly away from the optical surface.

The mould members are provided with opposing planar ring surface portions 58 and 59 similar to ring surface portions 30 and 31 in Figure 3a and for a similar purpose. The female mould member has a further cylindrical portion 60 outwardly of the ring portion 59, and the inner surface 61 of portion 60 is slightly roughened. The ring portion 58 of the male member has an annular groove 62 close to its outer edge to produce an annular resilient beak 63 dimensioned to be a resilient fit within the roughened cylindrical portion 60. Accordingly, the beak and the roughened portion provide a locking or ratchet effect as the male member moves towards the female member during assembly of the mould members and during subsequent curing. This embodiment is particularly suitable for the casting of lenses from monomer mixtures with highly volatile components, when the moulds must be relatively firmly sealed together. During curing the male mould member can travel towards the female member to compensate for monomer shrinkage, as with the earlier described embodiments.

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I CLAIM:

1. A plastics material mould for casting a contact lens from curable material which shrinks during curing, said mould comprising:
male and female mould members adapted to fit together to define a mould cavity;
said male and female mould members each presenting a curved surface for moulding a respective desired optical surface of a contact lens;
said male and female mould members being adapted to permit the mould members to move towards each other during curing of said curable material introduced into the mould cavity to cast a lens; and wherein
said male mould member has a shoulder adjacent and circumferentially surrounding its optical curved surface;
said female mould member presents a generally cylindrical surface adjacent and circumferentially surrounding its optical curved surface; and
said shoulder is a circumferentially continuous slidable fit with said generally cylindrical surface when the mould members are assembled to permit the mould members to move slidably towards each other during curing of said curable material introduced into the mould cavity to cast a lens.

2. A mould as claimed in claim 1, wherein said shoulder presents a substantially right-angled external corner in any cross-section around its circumference.

3. A mould as claimed in claim 2, wherein said shoulder of said male mould member presents a first planar annular surface perpendicular to the lens axis and

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facing the female mould member, and a second right circular cylindrical surface, said external corner being formed by the junction of said first and second surfaces.

4. A mould as claimed in any one of claims 1-3 wherein said generally cylindrical surface of said female mould member is a frusto-conical surface tapering outwardly away from the optical curved surface of the female mould member at a taper angle of up to substantially 10^{o}.

5. A mould as claimed in any one of claims 1-3 wherein said generally cylindrical surface of said female mould member is substantially a right circular cylindrical surface.

6. A mould as claimed in any one of claims 1-3 wherein said generally cylindrical surface of said female mould member comprises first, second and third surfaces in succession away from the optical curved surface of the female mould member,
said first surface is a frusto-conical surface tapering outwardly away from the optical curved surface of the female mould member at a taper angle of up to substantially 10^{o}, for providing said slidable fit with the shoulder of the male mould member,
said second surface is substantially a right circular cylindrical surface to improve sealing of the mould members together upon assembly, and
said third surface is a frusto-conical surface tapering outwardly away from the optical curved surface of the female mould member.

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7. A mould as claimed in claim 1 wherein said male and female mould members are provided with opposing planar ring surface portions disposed outwardly of the slidable fit portion, said opposing planar ring surface portions seating against one another when the mould members are assembled for curing the curable material to cast a lens.

8. A mould as claimed in claim 7 wherein the planar ring surface portion of the male mould member is adapted to create a circumferential hinge zone about which the surface portion can move pivotally to permit said relative movement of the mould members during curing.

9. A mould as claimed in any one of claims 1-3 wherein said male and female mould members are provided one each with a circumferential roughened or ratchet surface and a circumferential resilient beak disposed outwardly of the slidable fit region, whereby said beak and said roughened surface engage one another to tend to lock the mould members together when they are assembled for curing the curable material to cast a lens.

10. A mould as claimed in any one of claims 1-3 wherein said mould members are provided with integral means for mounting the assembled mould members onto the spindle of a lathing machine.

11. A method for casting a contact lens from curable material which shrinks during curing, said method comprising:

providing disposable male and female mould members which fit together to define a mould cavity and each present a curved surface for moulding a respective desired optical surface of the contact lens;

charging the female mould member with a predetermined amount of monomeric material;

assembling the charged female mould member with the male mould member;

curing the monomeric material while permitting the mould members to move towards each other; and

removing the cast lens from the mould members; and further comprising:

providing said male mould member with a shoulder adjacent and circumferentially surrounding its optical curved surface:

providing said female mould member with a generally cylindrical surface adjacent and circumferentially surrounding its optical curved surface;

and wherein said assembling step comprises assembling the charged female mould member with the male mould member with the shoulder being a circumferentially continuous slidable fit with the generally cylindrical surface; and

said curing step permits the male and female mould members to slide towards each other during curing.

Fig. 1.

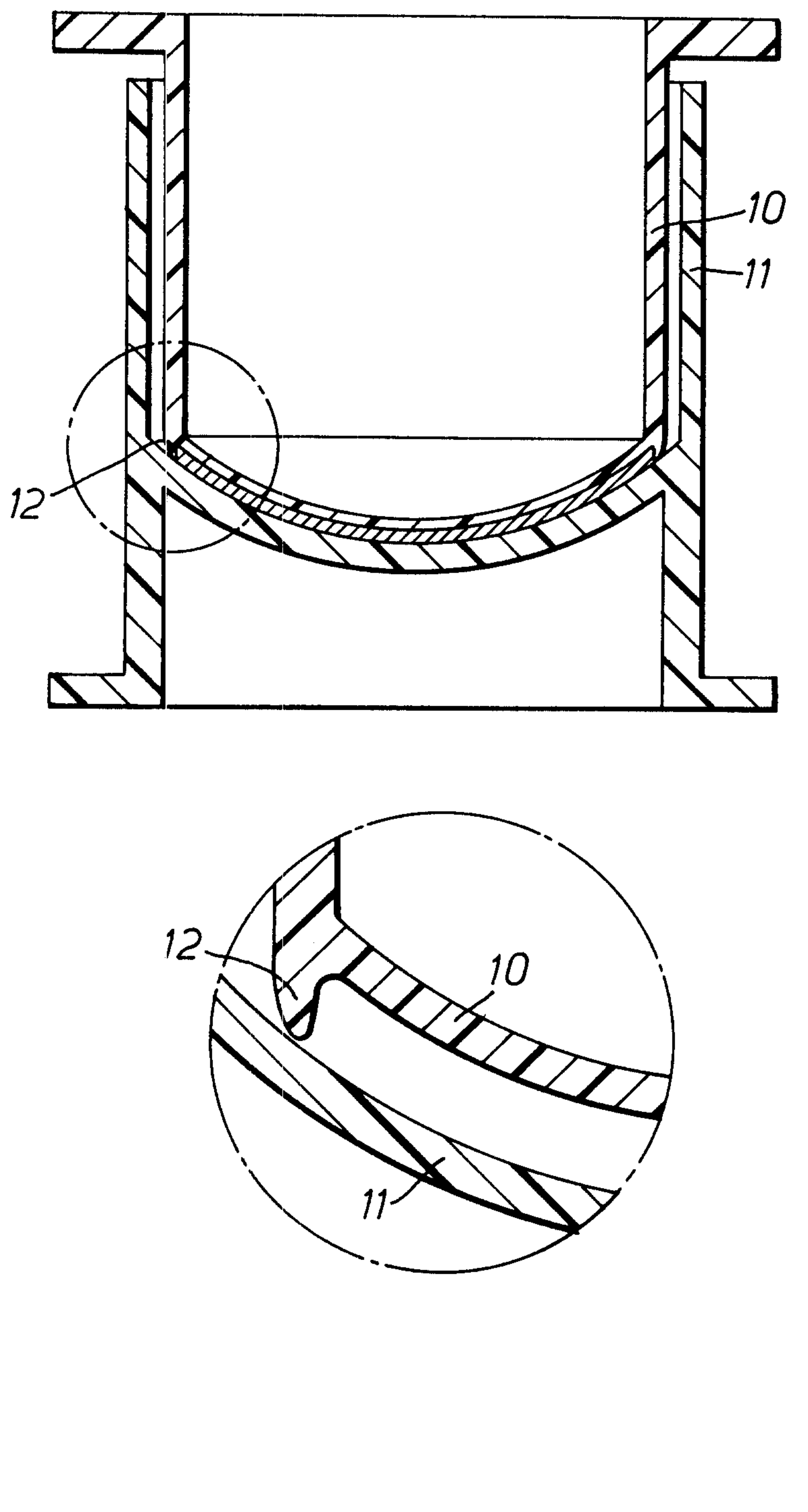

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Fig.2a.

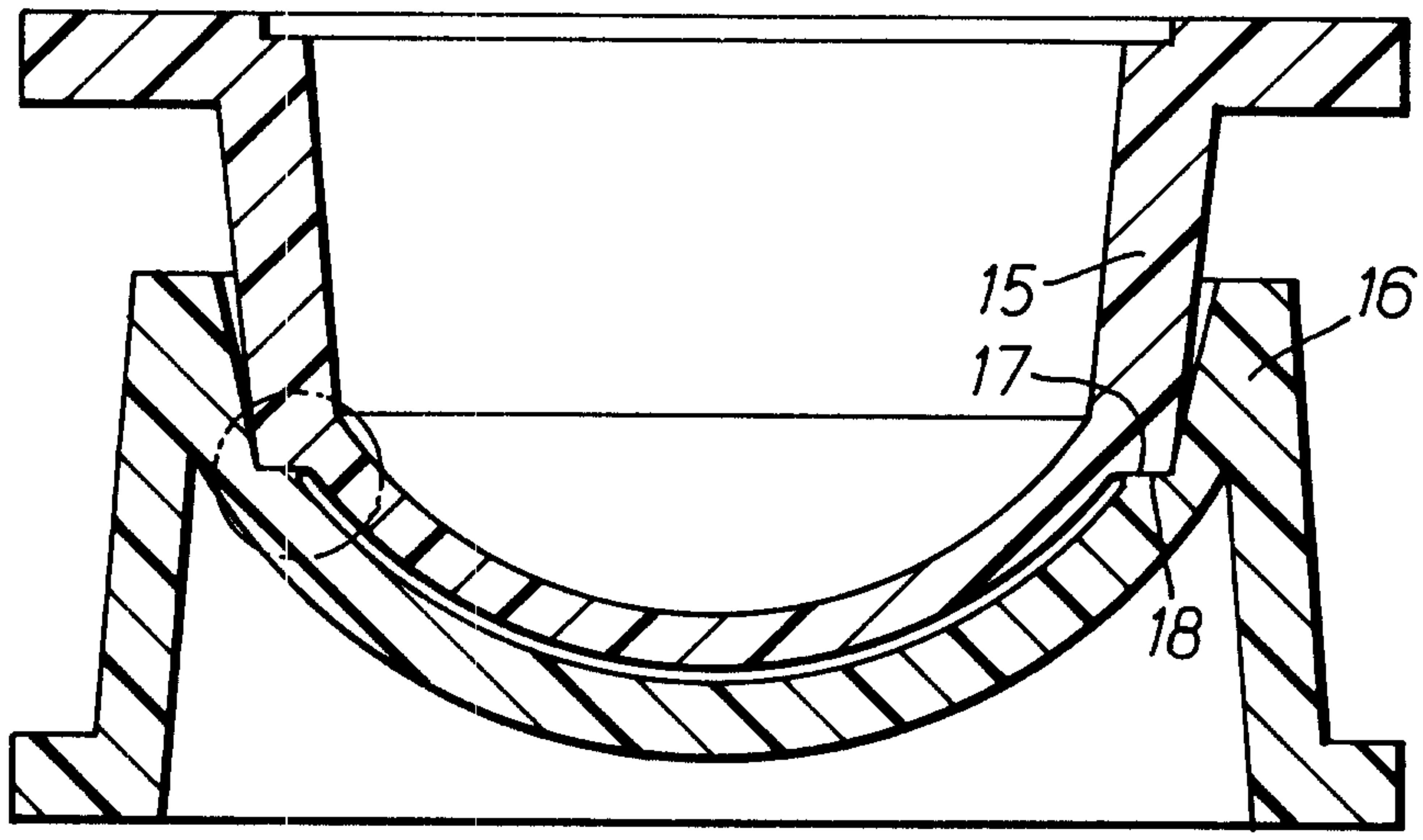


Fig.2b.

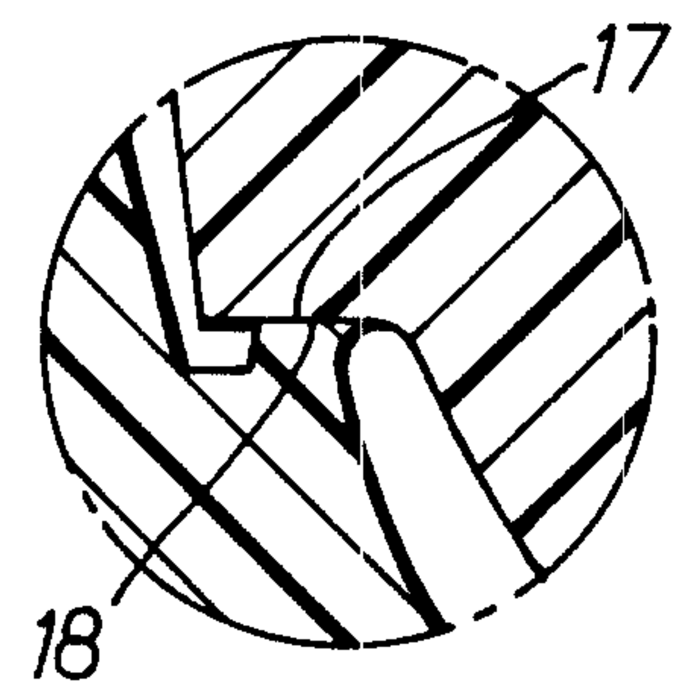


Fig.2c.

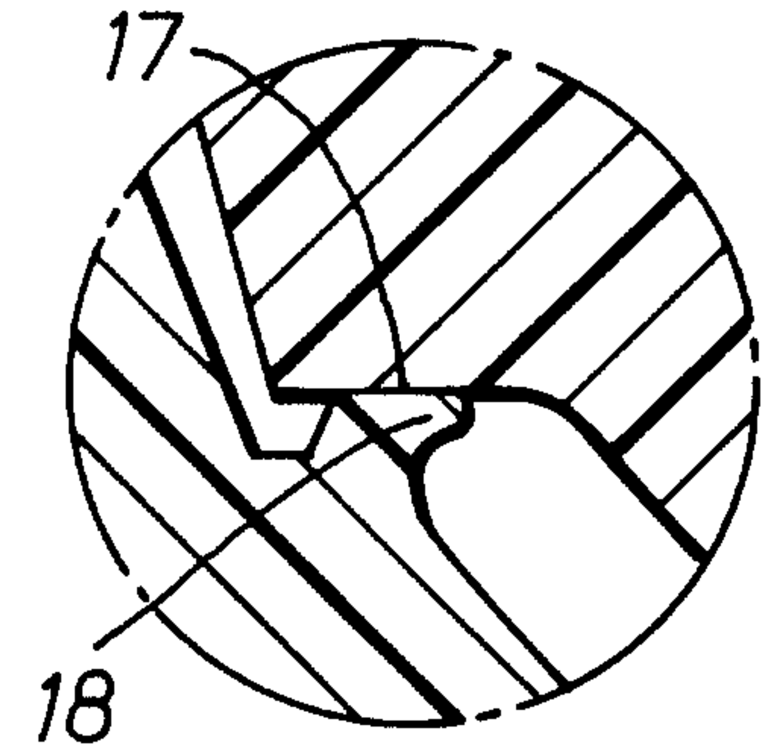


Fig. 3a.

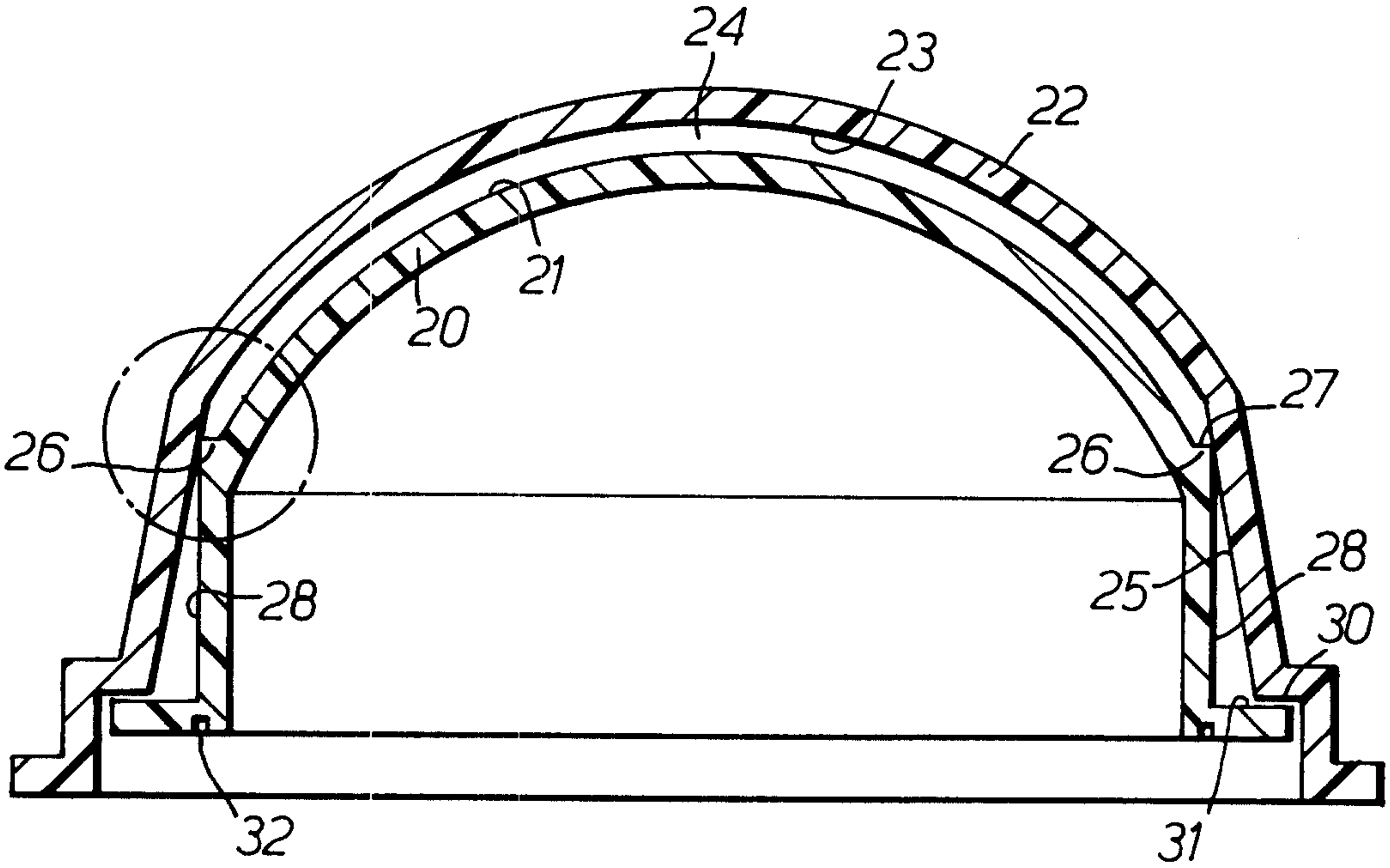


Fig. 3b.

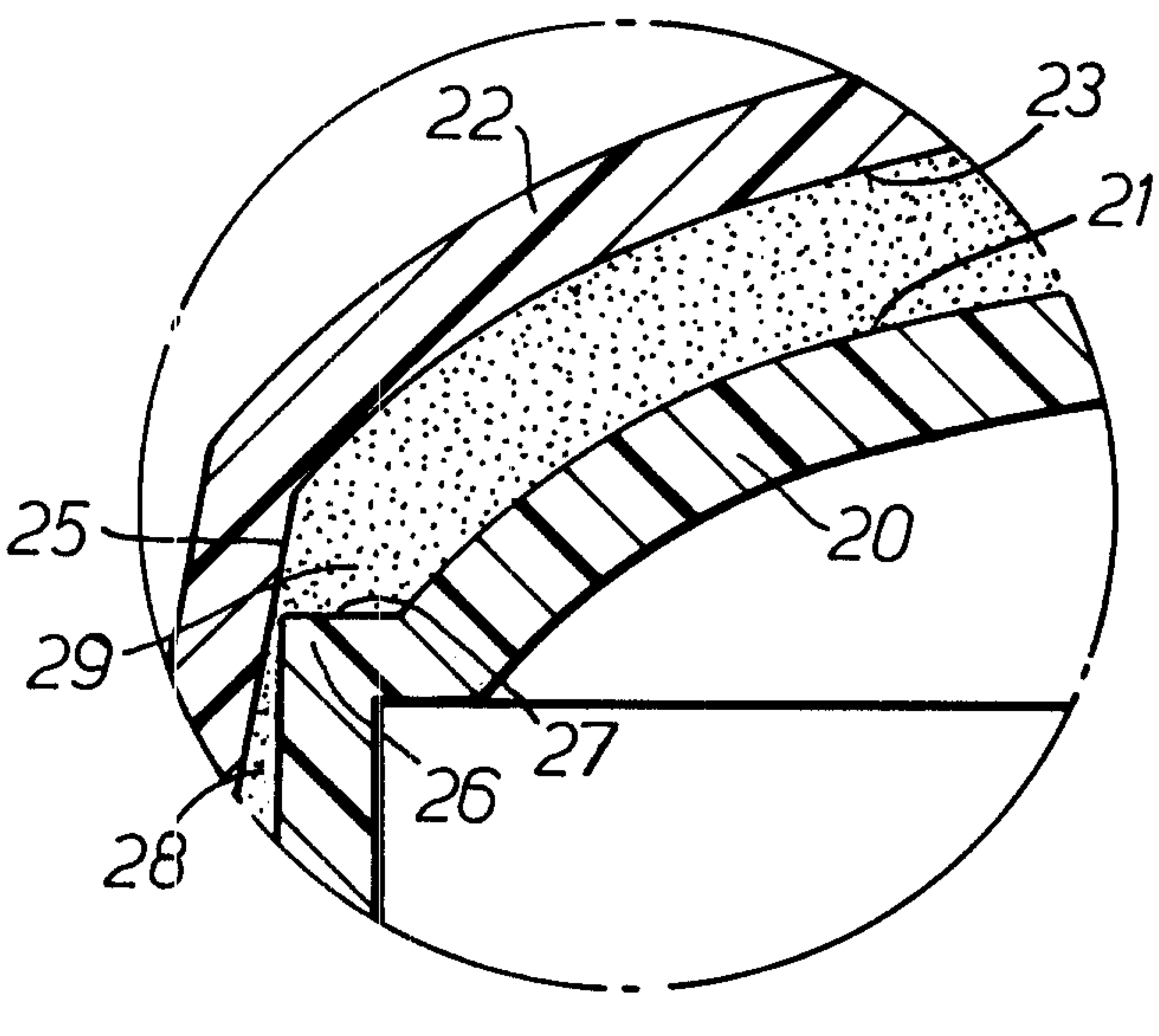


Fig.4.

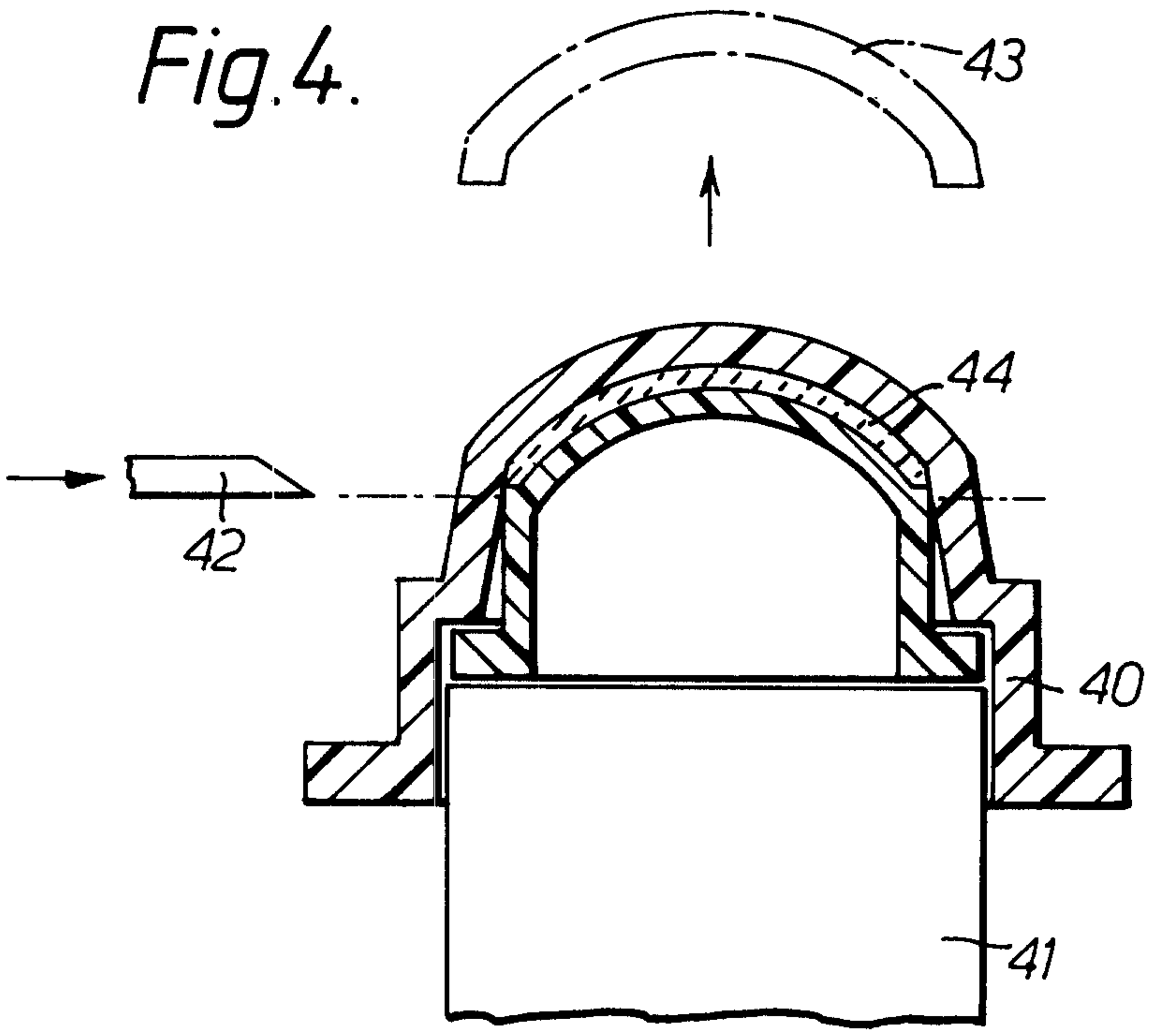
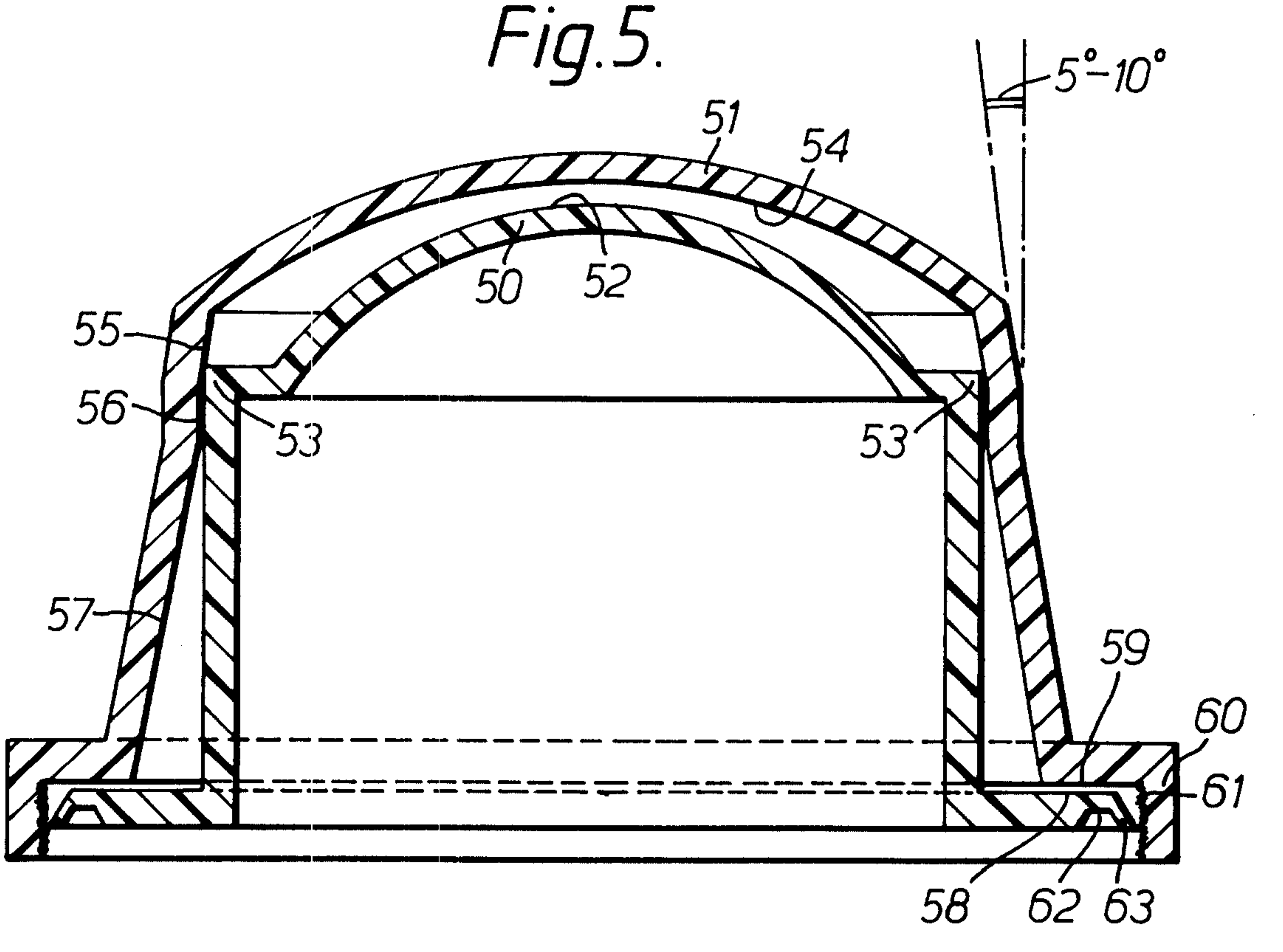
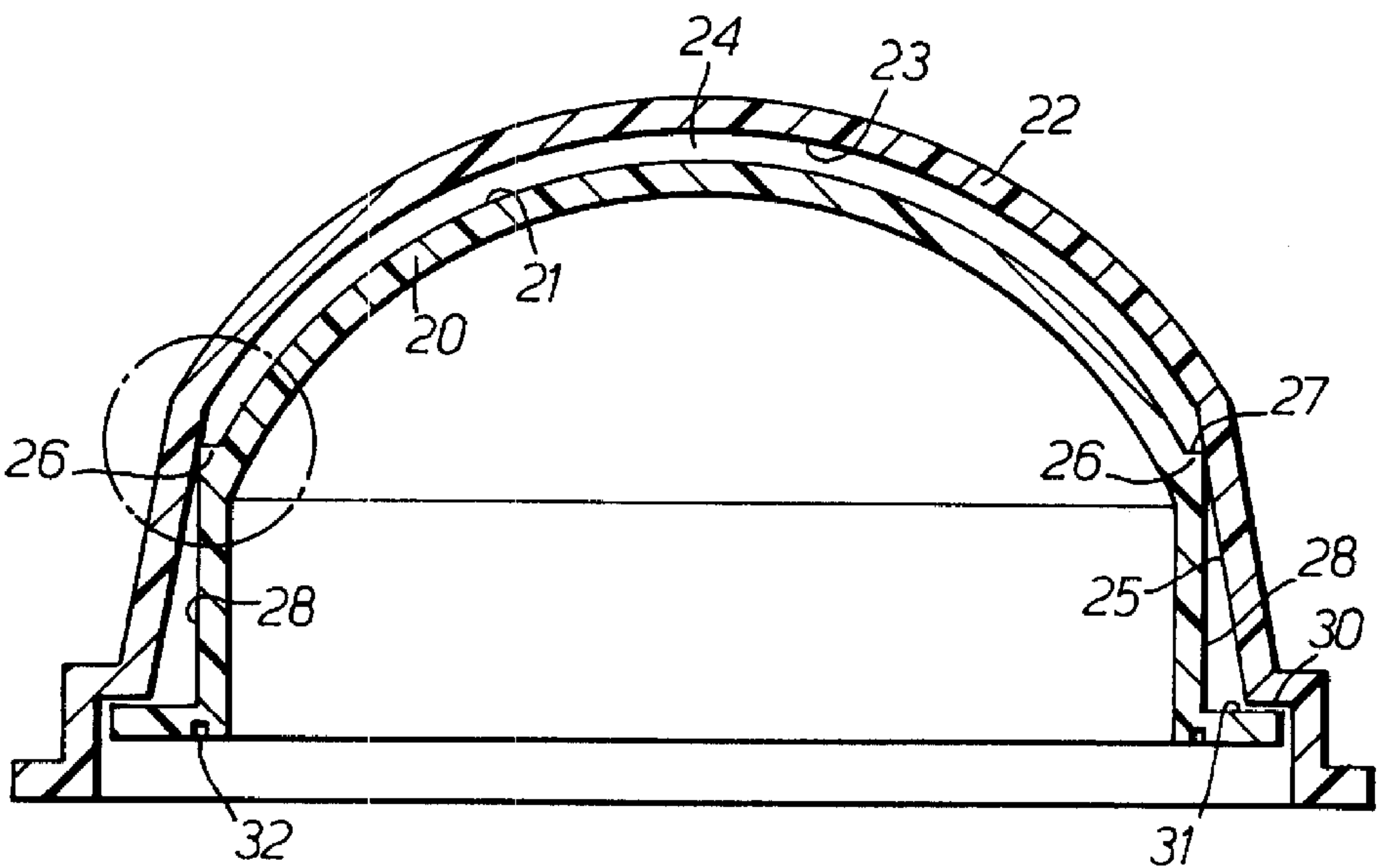


Fig.5.

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