(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
14 June 2001 (14.06.2001)

PCT

(10) International Publication Number
WO 01/42647 A2

(51) International Patent Classification[7]: F03D 1/06

(21) International Application Number: PCT/NL00/00872

(22) International Filing Date: 29 November 2000 (29.11.2000)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
1013807 9 December 1999 (09.12.1999) NL

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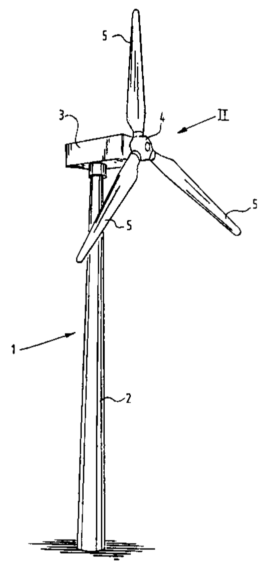
(81) Designated States (*national*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:
— *Without international search report and to be republished upon receipt of that report.*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: WIND TURBINE ROTOR, AND HUB AND EXTENDER THEREFOR



(57) Abstract: The invention relates to a rotor for a wind turbine, which wind turbine comprises: a support construction, for instance a post, a column or a spatial tube construction; and a generator supported by this support construction and having an outward protruding horizontal shaft which is rotatably mounted and carries a generator rotor forming part of the generator; which rotor comprises the following rotor parts: a hub with first coupling means for releasable rigid coupling of the hub in coaxial relation to the end of the shaft; and a number of blades which are coupled rigidly and releasably to the hub by means of respective second coupling means via the ends of their respective blade roots; wherein the hub and each blade root consist of composite material.

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WIND TURBINE ROTOR, AND HUB AND EXTENDER THEREFOR

The invention relates to a rotor for a wind turbine,

which wind turbine comprises:

a support construction, for instance a post, a column or a spatial tube construction; and

a generator supported by this support construction and having an outward protruding horizontal shaft which is rotatably mounted and carries a generator rotor forming part of the generator;

which rotor comprises the following rotor parts:

a hub with first coupling means for releasable rigid coupling of the hub in coaxial relation to the end of the shaft; and

a number of blades which are coupled rigidly and releasably to the hub by means of respective second coupling means via the ends of their respective blade roots.

The hub of a known wind turbine rotor is embodied in cast iron.

The drawback of a cast iron hub, particularly for large rotors, is that they are very heavy due to the nature of the material and the necessary mechanical properties and safety margins.

It is an object of the invention to embody a rotor for a wind turbine such that, with retention and even improvement of the required mechanical properties and while retaining the required safety margins, it can be substantially lighter and can be manufactured more cheaply.

It is another object of the invention to embody a rotor such that it is interchangeable with existing cast iron rotors without adaptation.

In respect of the above the rotor according to the invention has the special feature that the hub and each blade root consists of composite material.

The main function of the hub is to carry the bending moments introduced at the blade flanges and to transfer the torsional moment through the shaft flange to the drive train unit.

It is important to split the function of the hub for:

a) bending moment and

b) torsion moment

considering following design rules:

* optimising the outer shell for the bending moments between the blade flanges and the main shaft flange;

* tailoring of the outer shell with adequate lay-up to the stress flow

* minimizing laminate thickness so that ideally all areas have the same stress level, thus utilizing the material homogeneously, and avoiding stress concentrations.

An access hole is necessary for mounting and maintenance.

The root section of rotor blades are usually made of composite materials, thus a composite cylinder is connected to the hub flange. The metal flange connects with nearly the same geometry this cylinder to a metal part, thus resulting in a big increase of stiffness.

There exist basically three design concepts:

. ball geometry

. triangle geometry

. ball with integrated extenders

A composite material is defined as a material comprising at least two components with mutually differing properties, particularly in respect of strength and rigidity.

There also exist composite materials comprising a fibre reinforcement embedded in a plastic mass or matrix.

A specific embodiment of the rotor according to the invention has the special feature that the second coupling means comprise an extender, both ends of which can be rigidly and releasably coupled to the hub and the end of the relevant blade root by means of third and fourth coupling means, which extender consists of composite material.

An extender is an element for arranging between a blade root and the root of a rotor blade whereby the effective rotor diameter will be increased while maintaining the blade lengths, thus increasing the swept area and consequently the energy production. A prerequisite here is that the generator and the blades have a sufficient electrical and mechanical capacity.

The use of composite material for the hub and blade roots has the further advantage compared to cast iron that a composite material is not subject to corrosion.

A specific embodiment has the special feature that the hub has a central hole for accommodating the end of the shaft.

A very light but nevertheless strong construction can be obtained with an embodiment in which the hub is hollow and the central hole is bounded by a cylindrical bush.

Easy to manufacture is an embodiment wherein the hub consists of mutually adhered hub parts.

In order to achieve a great mechanical rigidity and strength the rotor can in accordance with a particular aspect of the invention have the special feature that the hub comprises two mutually adhered shells and said bush, which bush is adhered to at least one of the shells by a number of shores, which shores consist of composite material. Likewise in order to increase mechanical strength and rigidity, the rotor can in accordance with an aspect of the invention have the special feature in the latter embodiment that the cylinder comprises an inner cylinder adhered to the one shell and an outer cylinder adhered to the other shell.

The rotor can also be designed such that the shells are mutually adhered along a plane extending substantially transversely of the axis of the hub.

The above discussed rotor with the hub consisting of diverse components also has the advantage compared to cast iron that the hollow form can be realized by assembling a number of components. Composite materials can be adhered to each other relatively simply and with a great strength and lifespan, for instance with glue or a welding process. Such an adhesion has been found to be very reliable in other applications.

A known cast iron hub consists of a substantially homogeneous cast iron mass. The local mechanical properties cannot therefore vary from place to place. As a result the rotor must generally be overdimensioned such that it complies with stringent safety margins.

In contrast to this known art the invention provides in accordance with a particular aspect a rotor in which the composite material of the relevant rotor part is a plastic matrix and a reinforcement of fibres embedded therein, wherein the density and direction of the fibres are chosen such that at every position the rotor part complies with requirements set on the basis of predicted mechanical loads in respect of mechanical strength, rigidity and damping. With this embodiment the rotor can satisfy very stringent safety requirements and nevertheless be of very light construction. A rotor according to the invention can for instance be optimized by mechanical analyses, on the basis of which the density and direction of the fibres can be locally chosen in optimal manner. In addition, using for instance casting techniques and special moulds, the wall thickness can be reduced locally in areas of lower load. Use of the above stated shores can make a substantial contribution to the lower weight of the rotor.

In accordance with yet another aspect of the invention the rotor has the special feature that the first, second, third and/or fourth coupling means comprise screw bolts and nuts co-acting therewith which engage on the respective two rotor parts for mutual coupling.

In this embodiment the rotor preferably has the special feature that the screw bolts are ordered in an annular configuration. The annular form can correspond in particular to a general circle shape.

The variant is recommended in this respect wherein the screw bolts extend in the direction of the local tensile force during operation of the wind turbine such that they are subjected only to respective tensile forces.

In order to enable realization of for instance a diameter transition, the rotor can have the special feature that said coupling means comprise flange means placed between the rotor parts for mutual coupling, in particular an annular flange, wherein said two rotor parts are each coupled to the flange means with an individual annular configuration of screw bolts, both of which configurations are substantially placed concentrically.

The invention further relates to a hub for a wind turbine rotor of the described type. This hub consists according to the invention of composite material.

The invention likewise relates to an extender as specified above for a wind turbine rotor according to the invention. This extender also consists of composite material.

The following considerations are applicable:

- integration of rotor blades, blade root, extender, blade flange and hub into one system with the composite material

- maintaining the same allowable external forces on the blade flanges, an iron hub can be easily substituted by a composite hub (exchangeability of blades)

- using composite material means not only a simple material substitution. The composite part is a consequence of the consideration of

. design

. production methods

. material properties.

Taking into account the excellent properties in fibre direction, the lay-up direction of the composite hub can be tailoring according to the stress flow in the hub. Furthermore, the wall thickness can be minimized in regions of minor loading. The design with composite also allows to introduce stiffeners, in order to achieve a high stiffness/weight ratio.

Also, it is quite common to use steel extenders, which are quite expensive, to enlarge the rotor diameter.

Here, the innovative idea is to define a complete rotor system. This rotor system consists of:

. rotor blades

. blade root extenders (in order to increase the swept area using the same blades),

. blade root adapters (in order to allow the installation of blades and hubs with different pitch circle diameters)

. hub

All these components can be made of composite materials. Thus, the complete rotating system can be made of the same material. This influences especially the system dynamics (moment of inertia, mass, material damping, and material structural stiffness) and the noise emission (transfer of structural born noise from the drive train unit through the hub to the rotor blades).

The hub stiffness is essential for both static and dynamic behaviour of the complete rotor system. For example, a minimum stiffness in flapwise direction is required for maintaining a minimum distance between the blade tip and the tower in the maximum static load case (extreme load while the turbine is running). Additional, the dynamic movements of one blade should not be transferred to other blades, as the hub is the foundation of the dynamic component rotor blade. Thus, from the system dynamic point of view, the stiffness/flexibility has to be optimised so that the rotor does not suffer from large vibrations in resonance situations.

Large movements, expressed by a high flexibility, allow the dynamic system "rotor" to react more smoothly to extreme loading, for example gusts, which is usually known by teetering hubs. For example, the flange section of a standard cast iron hub is about eight times stiffer (product E x l) than the composite blade root section, only taking into account the different Young's modulus (E = 21.000 MPa for glass fibre/epoxy composites and E = 170.000 Mpa for GGG 40), while the moment of inertia I is approximately the same. For the interesting phenomenon called "edgewise vibrations", the optimisation of the hub stiffness in edgewise direction can contribute, together with improved material damping, to a reduction of problems in this area.

The invention will now be elucidated with reference to the annexed drawings. Herein:

figure 1 shows a perspective view of a wind turbine according to the invention;

figure 2 shows a partly cut-away perspective view of an essential part of the rotor as indicated with II in figure 1;

figure 3 shows a cut-away perspective view of detail III of figure 2;

figure 4 is a cut-away perspective view of another embodiment of a hub according to the invention;

figure 5 is a broken-away perspective view of detail V of figure 4;

figure 6 shows in partly broken-away perspective view a hub with three blade roots coupled thereto;

figure 7 is a cut-away perspective view of detail VII of figure 6;

figure 8 shows a schematic perspective view of a part of a rotor according to the invention, wherein the constituent parts are shown for the sake of clarity at some mutual distance;

figure 9 shows in perspective view two shells for manufacturing a hub;

figure 10 is a perspective view of a shell with a central bush adhered thereto;

figure 11 is a perspective view of the shell with the bush of figure 10, wherein the construction is strengthened by shores;

figure 12 is a perspective view of a finished hub.

Figure 1 shows a wind turbine 1 comprising a support construction 2 embodied as a post, an electrical generator 3 supported thereby and having a shaft (not shown) which carries a hub 4, to which hub three blades 5 are connected in angularly equidistant relation.

Figure 2 shows hub 4. This takes a hollow form and carries blades 5 via blade roots 6. On the front of hub 4 is situated a hole 7 through which the interior of the hub is accessible. On the rear of the hub is likewise situated a hole, which is designated 8 and surrounded by a ring or holes 9. Generator shaft 10 bears on its end a flange 11 with a ring of holes 12 which can be placed in register with the ring or holes 9. Coupling bolts can be placed through the respective holes 9 and 12 to couple hub 4 to flange 11.

Blade roots 6 are coupled to hub 4 in analogous manner. Each blade root bears a T-bolt 13 (see figure 3). This is a bolt which co-acts with an associated insert 14 in root 6, which insert 14 is provided with a threaded hole for coupling to bolt 13. On the other side the bolt

13 co-acts with a nut 15 extending in the inner cavity of hub 4. For this purpose a ring of holes 16 is arranged in the hub round the three respective holes 17. Arranging and tightening of said fixing bolts and nuts can take place via hole 7.

Hub 4 consists of composite material, as does blade root 6.

Figure 4 shows a hub 17 which takes a completely hollow form. In order to accommodate the end of a generator shaft (not shown), hub 17 has a central bush 18 comprising an outer bush 19 and an inner bush 20. Hub 17 consists of two shells 21,22 as will be described below with reference to figures 9,10,11 and 12. Shells 21,22 are mutually adhered via a plane extending transversely of the rotation axis 23 of hub 17. This corresponds with the adhesion seams designated 24.

A blade root 25 is connected to hub 17.

The bush 18, or at least the inner bush 20 thereof is, for the present invention, regarded as a separate component from the hub 17. Therefore it can be manufactured from metal, steel or the like. It can also have a different shape in cross section, for example square, triangular, etc.

Figure 5 shows the manner in which the respective diameters of respective holes 117' and blade roots 25 are adapted to each other.

Use is made of an annular flange 26 which is coupled respectively to hub 17 and each blade root 25 by means of respective rings of T-bolts 27. The specification of the T-bolt structure has already been given with reference to figures 2 and 3.

Attention is drawn to a difference between the structure of figure 3 and that of figure 5. Bolts 13 according to figure 3 are in principle only under strain of tension in their axial direction. In the structure according to figure 5 it is not possible as a result of the different diameters of the rings 27 and 28 to prevent a torque being exerted on annular flange 26 in combination with a lateral force component on bolts 13.

Figure 6 shows a hub 29, of which the parts 31 directed toward blade roots 30 take a form such that they connect smoothly onto these blade roots 30.

Figure 7 shows the T-bolt construction with which blade roots 30 are fixed to said parts 31. said end parts 31 are provided with continuous holes in which is accommodated a support element 32 provided with a continuous hole. Similarly to the rod-like elements 14, support element 32 is mechanically strong, being manufactured for instance from steel. Just as insert 14, it serves to distribute the tensile force in bolt 13 over the available surface, i.e. the surfaces directed towards each other of insert 14 and support element 13. It is noted that the shown structure is very suitable due to the high mechanical strength of the applied composite materials for both hub 29 and blade root 30.

Figure 8 shows schematically the structure shown in figure 2, wherein the blades are effectively lengthened by applying the respective extenders 33. These latter are likewise manufactured from composite material and can be coupled rigidly and releasably in any appropriate manner to hub 4 on one side and the associated blade root 6 on the other. Extenders 33 can for instance be coupled to hub 4 in the manner shown in figure 3, while the coupling to blade root 6 is for instance embodied in the manner shown in figure 7.

Figure 9 shows the two shells 21 and 22 as according to figure 4.

Figure 10 shows that inner bush 20 is adhered to shell 22.

Figure 11 shows that shores 33 are adhered between shell 22 and inner bush 20. This results in a substantial stiffening and strengthening while retaining the low weight.

After outer bush 19 has been adhered in similar manner to shell 21 (or is already formed thereon during the production process), shells 21,22 can be permanently coupled to each other along the plane defined by adhesion seams 24 as according to figure 4. After this process the hub 17 is finished.

It is noted that the mention of the required holes has been omitted in this description, for which aspect reference is made to for instance figure 4.

It is further noted, that in the light of the present invention, the bush described above and shown in figs. 4 and 10 is not necessarily considered a part of the hub, but rather as a coupling for arranging the hub on the generator shaft which is for instance shown - in a different attachment configuration - in fig. 2. Therefore the bush can, contrary to the hub according to the invention, be manufactured from metal, steel, etc. The bush can also have a different cross section shape than circular, e.g. square, triangular, etc.

CLAIMS

1. Rotor for a wind turbine,

which wind turbine comprises:

a support construction, for instance a post, a column or a spatial tube construction; and

a generator supported by this support construction and having an outward protruding horizontal shaft which is rotatably mounted and carries a generator rotor forming part of the generator;

which rotor comprises the following rotor parts:

a hub with first coupling means for releasable rigid coupling of the hub in coaxial relation to the end of the shaft; and

a number of blades which are coupled rigidly and releasably to the hub by means of respective second coupling means via the ends of their respective blade roots;

characterized in that

the hub and each blade root consist of composite material.

2. Rotor as claimed in claim 1, wherein the second coupling means comprise an extender, both ends of which can be rigidly and releasably coupled to the hub and the end of the relevant blade root by means of third and fourth coupling means, which extender consists of composite material.

3. Rotor as claimed in claim 1, wherein the hub has a central hole for accommodating the end of the shaft.

4. Rotor as claimed in claim 3, wherein the hub is hollow and the central hole is bounded by a cylindrical bush.

5. Rotor as claimed in claim 4, wherein the hub consists of mutually adhered hub parts.

6. Rotor as claimed in claim 5, wherein the hub comprises two mutually adhered shells and said bush, which bush is adhered to at least one of the shells by a number of shores, which shores consist of composite material.

7. Rotor as claimed in claim 6, wherein the cylinder comprises an inner cylinder adhered to the one shell and an outer cylinder adhered to the other shell.

8. Rotor as claimed in claim 6, wherein the shells are mutually adhered along a plane extending substantially transversely of the axis of the hub.

9. Rotor as claimed in claim 1, wherein the composite material of the relevant rotor part is a plastic matrix and a reinforcement of fibres embedded therein, wherein the density and direction of the fibres are chosen such that at every position the rotor part complies with requirements set on the basis of predicted mechanical loads in respect of mechanical strength, rigidity and damping.

10. Rotor as claimed in claim 1, wherein the first, second, third and/or fourth coupling means comprise screw bolts and nuts co-acting therewith which engage on the respective two rotor parts for mutual coupling.

11. Rotor as claimed in claim 10, wherein the screw bolts are ordered in an annular configuration.

12. Rotor as claimed in claim 11, wherein the screw bolts extend in the direction of the local tensile force during operation of the wind turbine such that they are subjected only to respective tensile forces.

13. Rotor as claimed in claims 10 and 11, wherein said coupling means comprise flange means placed between the rotor parts for mutual coupling, in particular an annular flange, wherein said two rotor parts are each coupled to the flange means with an individual annular configuration of screw bolts, both of which configurations are substantially placed concentrically.

14. Hub for a wind turbine rotor as claimed in any of the claims 1-13, which hub comprises:

first coupling means for releasable rigid coupling of the hub in coaxial relation to the end of a generator rotor shaft; and

second coupling means for releasable rigid coupling to the hub of a number of blades via the ends of their respective blade roots;

characterized in that

the hub consists of composite material.

15. Extender for a wind turbine rotor as claimed in any of the claims 1-13, which extender comprises:

third coupling means for releasable rigid coupling of the one end of the extender to a hub as claimed in claim 14; and

fourth coupling means for releasable rigid coupling of the other end of the extender to a blade root;

characterized in that

the extender consists of composite material.

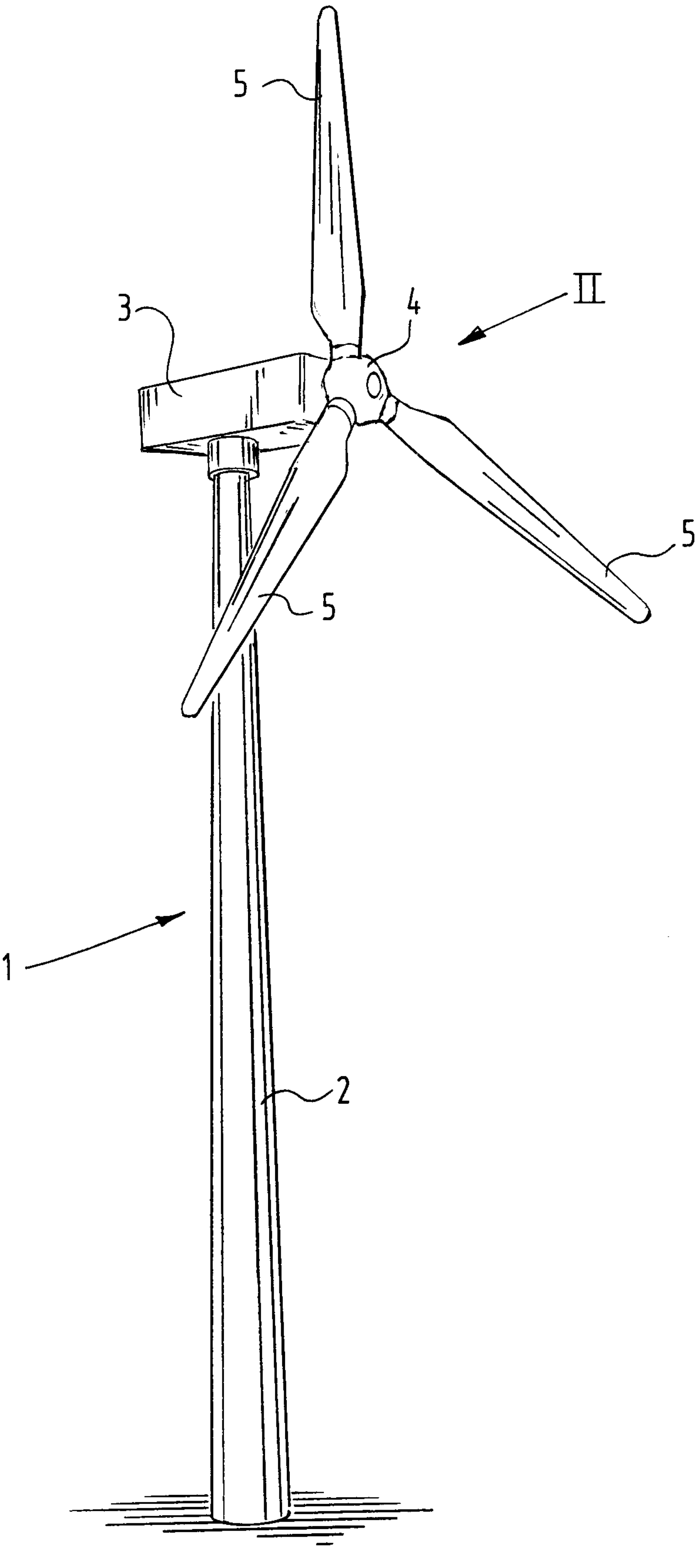


FIG. 1

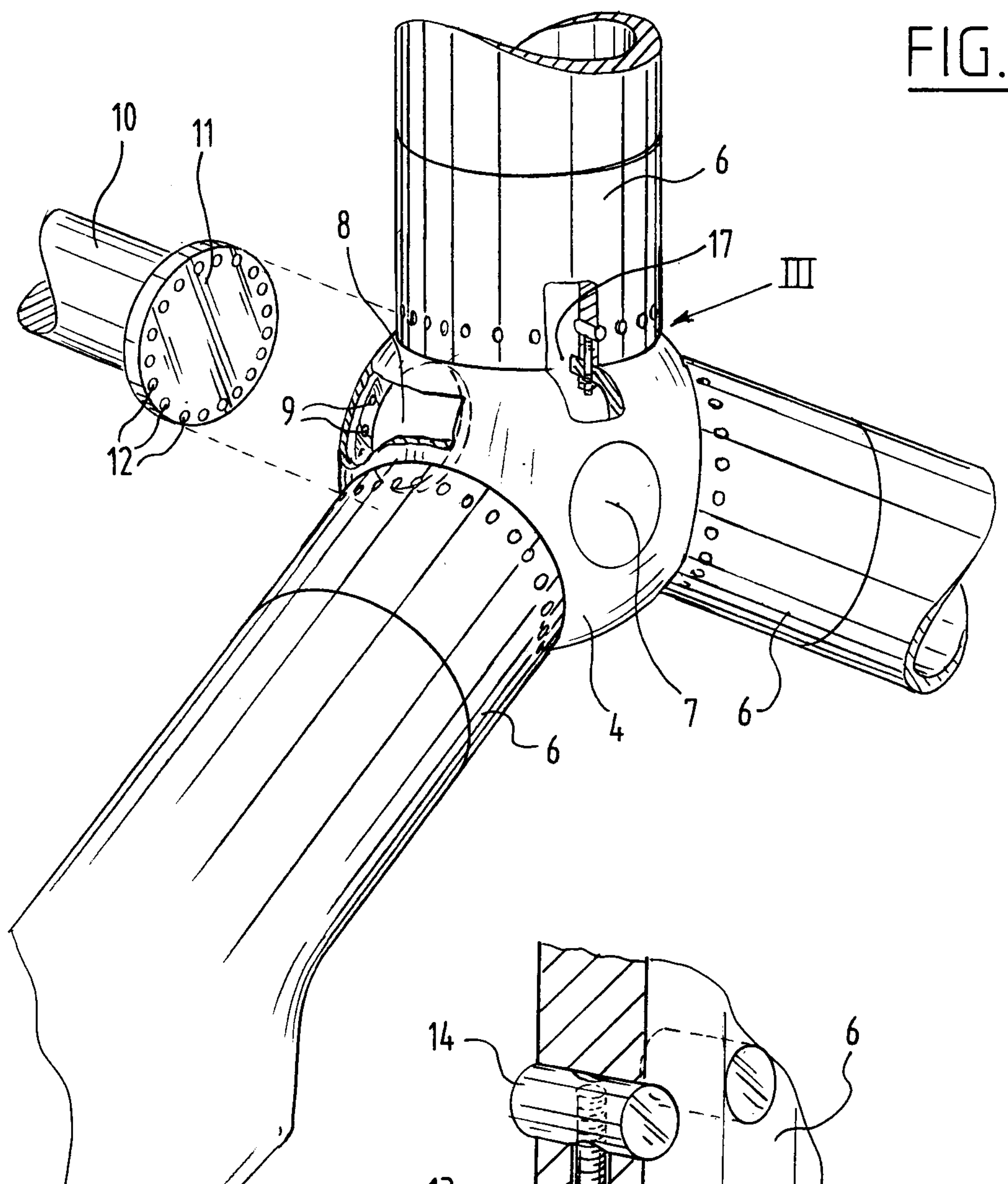


FIG. 2

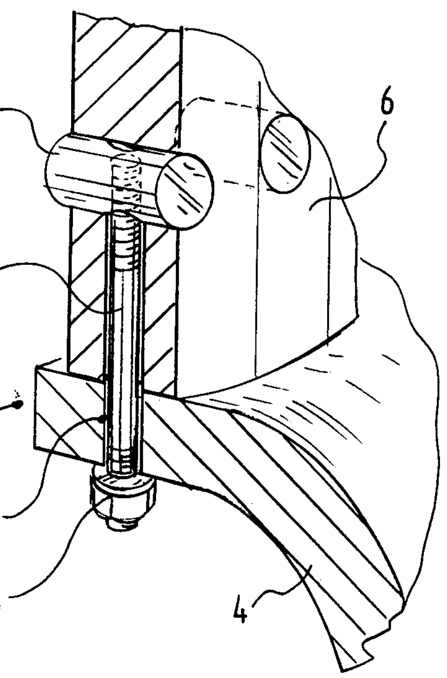


FIG. 3

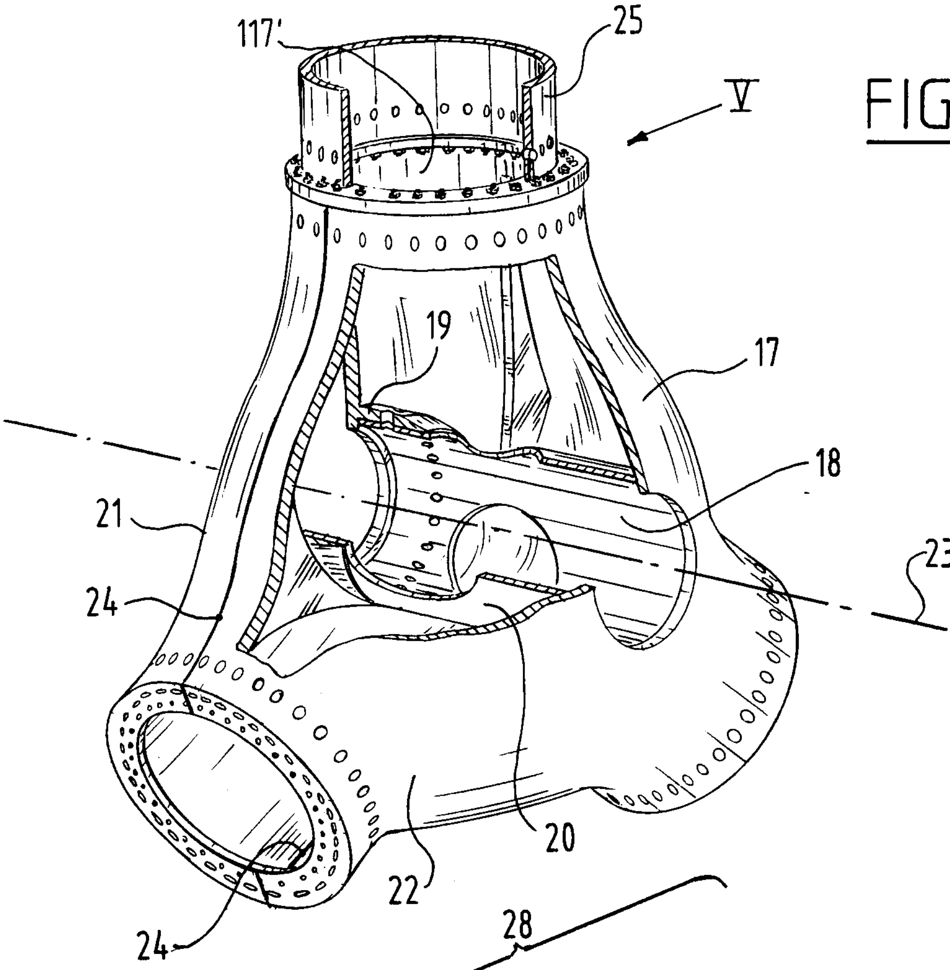


FIG. 4

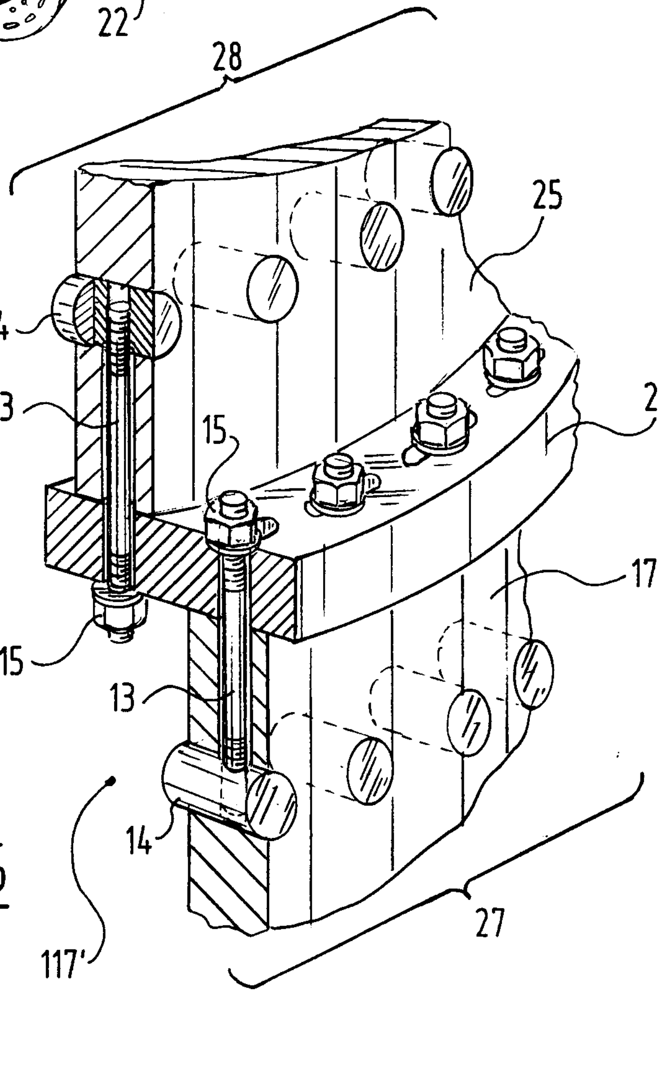
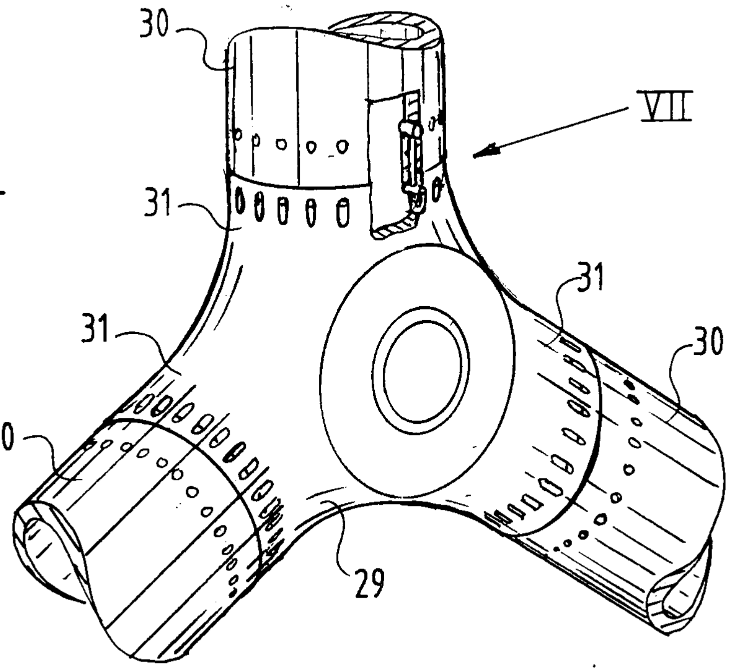


FIG. 5

FIG. 6



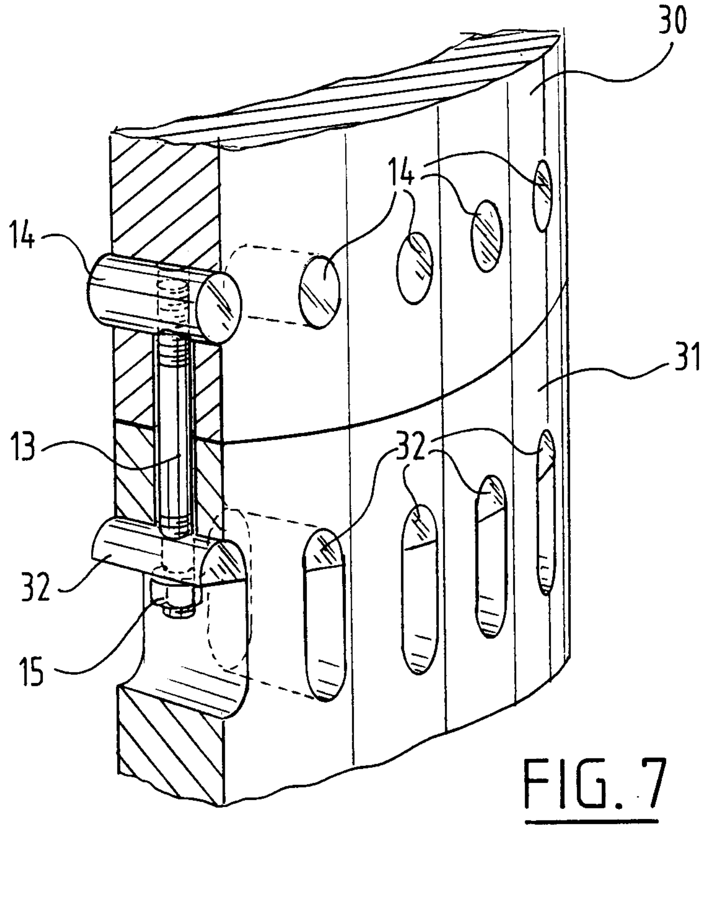


FIG. 7

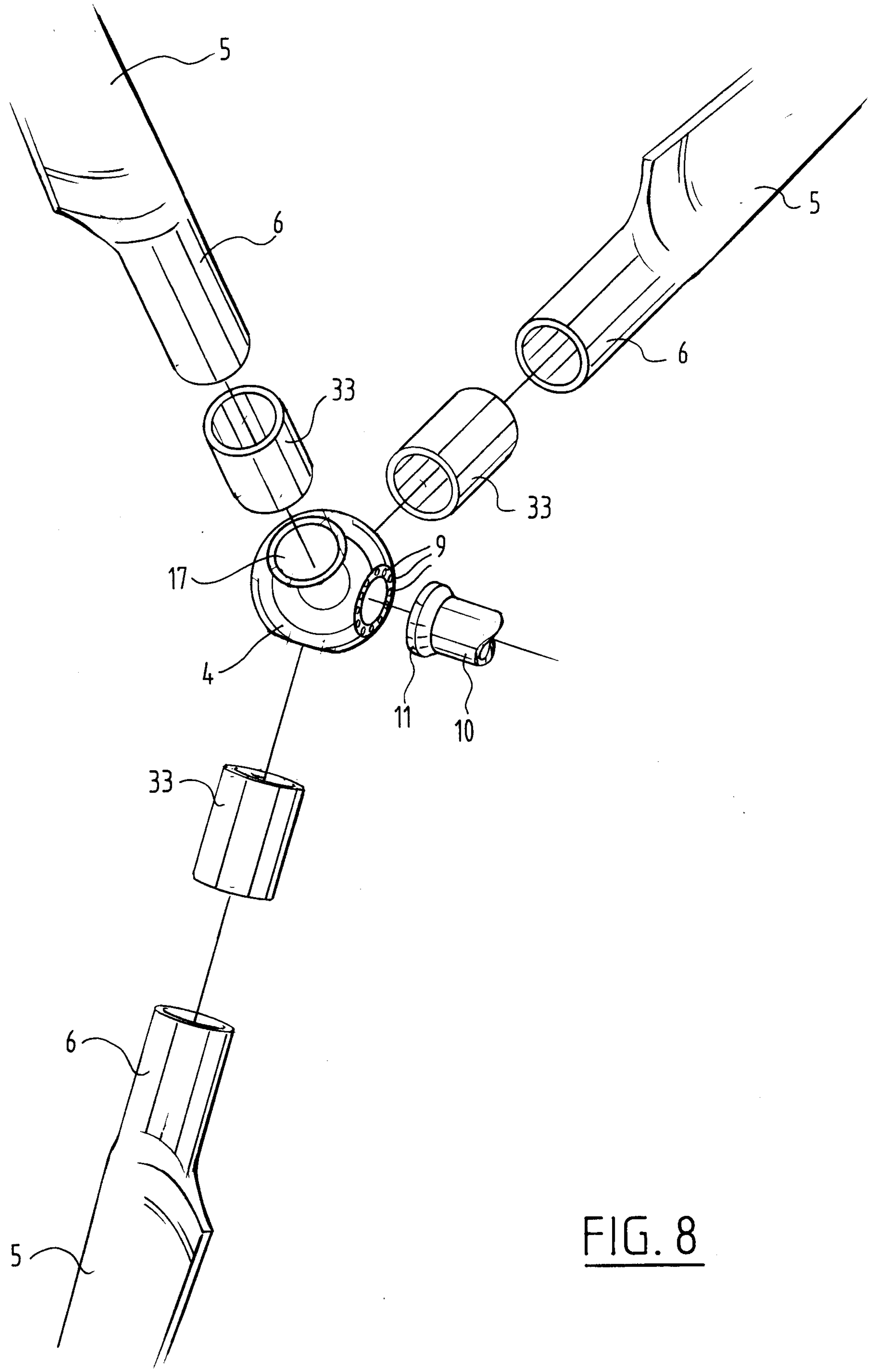


FIG. 8

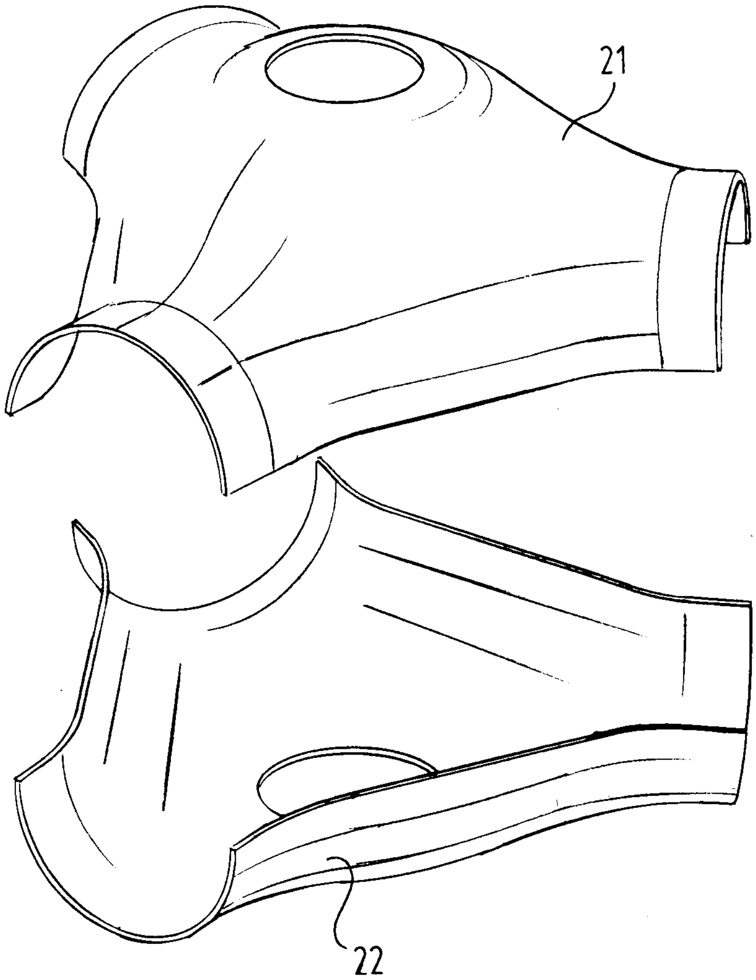


FIG. 9

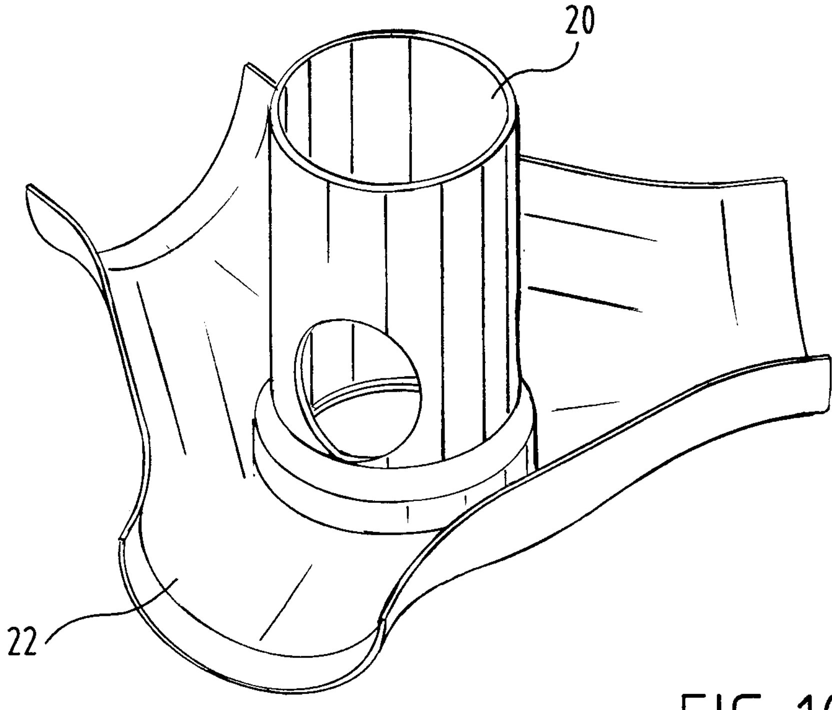


FIG. 10

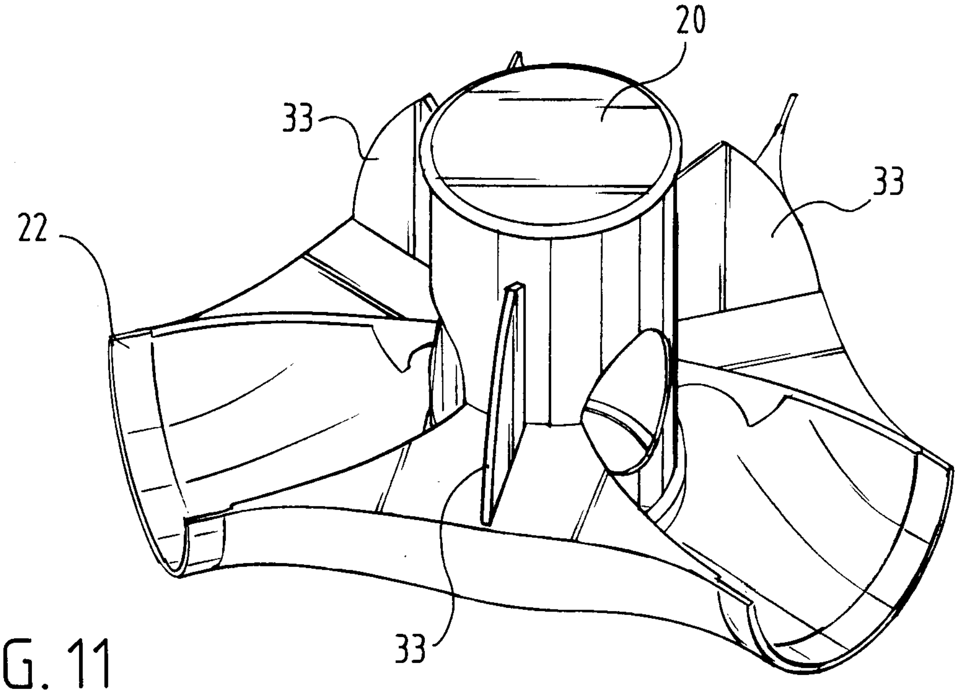


FIG. 11

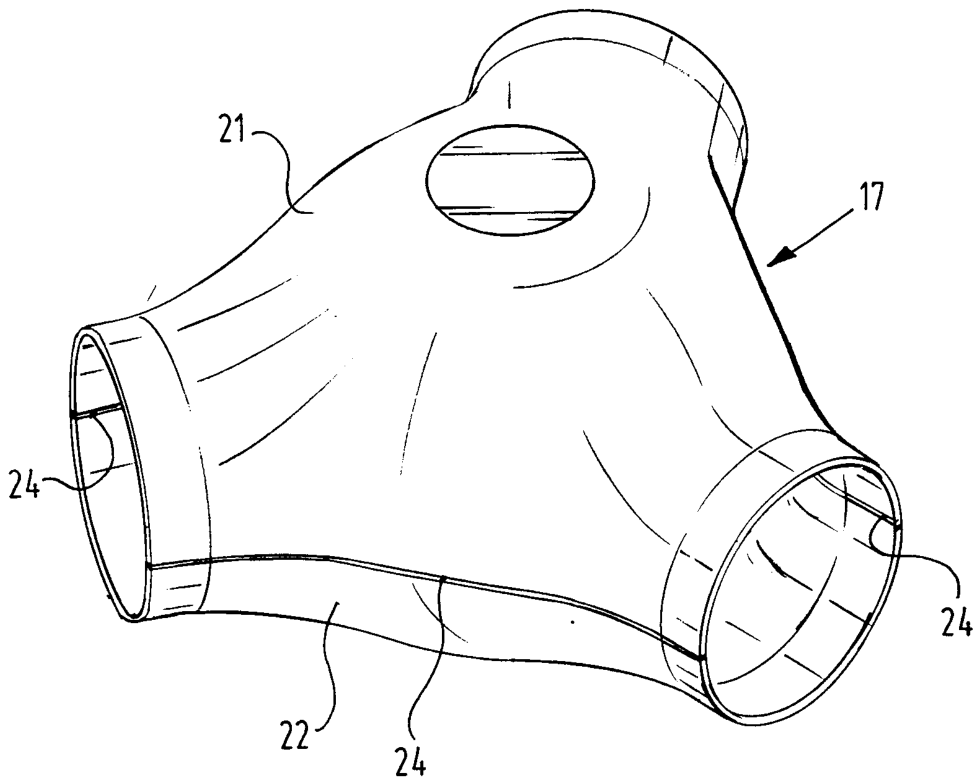


FIG. 12