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FOUNDATION PILE FOR A WIND MOTOR

The present invention relates to a foundation pile which is designed in particular to accommodate a wind turbine.

Foundation piles are usually erected from cylindrical foundation pile segments arranged one above the other and connected to one another, as taught in the document US 2015/0376857 A. The foundation pile segments in turn are composed of one, two, or more partial-cylinder segments each made from a bent steel plate.

If a foundation pile segment is made from just a single partial-cylinder segment, the steel plate is bent along the length thereof in such a way that the longitudinal edges (material or sheet metal edges) facing each other in the bent state can be welded together. The opposite longitudinal edges are welded by means of a longitudinal weld seam.

If a foundation pile segment is made from two or more partial-cylinder segments, the partial-cylinder segments are connected to one another at the longitudinal edges by means of longitudinal welds. To connect the partial-cylinder segments, a number of longitudinal weld seams corresponding to the number of partial-cylinder segments is necessary.

The foundation pile is then assembled from a large number of correspondingly formed foundation pile segments by connecting adjacent foundation pile segments by means of a circular weld seam in such a way that the respective longitudinal axes of the foundation pile segments extend in a collinear manner relative to one another.

Consequently, a large number of weld seams with a large overall length are required to produce a corresponding foundation pile, as a result of which the manufacture of the foundation pile is complex and expensive. For example, for the production of two foundation pile segments, each with a height of 3 m and a diameter of 7 m, and for their connection, weld seams with a total length of 28 m are necessary, specifically two respective 3 m longitudinal weld seams for connecting the opposite side edges or material edges of the individual partial-cylinder sections and a 22 m circular weld seam for connecting the two foundation pile segments.

For foundation piles that are anchored in the seabed, diameters of 7 m (seven metres) and more are now common or desired. So that a foundation pile has sufficient stability to withstand these forces exerted by wind and water movements, the wall thickness of the foundation pile must be increased. In addition, there is the problem that the larger the diameter of a foundation pile, the less an increase in wall thickness will affect the stability thereof. Consequently, in the case of foundation piles with ever larger diameters, the wall

thicknesses must grow disproportionately to the diameter thereof.

However, large wall thicknesses lead to considerable additional effort and costs in the manufacture of a foundation pile. Bending a steel plate into a partial-cylinder segment becomes more and more complex as the wall thickness increases. Furthermore, welding together partial-cylinder segments to form a foundation pile segment and welding together the foundation pile segments to form a foundation pile with increasing wall thickness becomes more and more complex and therefore also more costly.

The object of the present invention is to provide a foundation pile that has increased stability and, despite increased stability, is simpler and cheaper to manufacture.

The object of the present invention is achieved by a foundation pile having the features of claim 1. Advantageous embodiments of the foundation pile of the present invention are described in the dependent claims.

More precisely, the object of the present invention is achieved by a foundation pile which comprises a stabilization device that is arranged within the foundation pile and is connected to at least two inner surface sections of the foundation pile, wherein compressive and/or tensile forces can be transmitted by means of the stabilization device, such that the stabilization device counteracts lateral deformation and/or torsional deformation of the foundation pile.

The stabilization device arranged within the foundation pile and connected to the inner surface sections of the foundation pile distributes within the foundation pile forces exerted on one side of the foundation pile, for example through the action of wind, waves, or tidal currents, by means of the stabilization device. The foundation pile according to the invention thus has increased lateral rigidity and increased torsional rigidity. Therefore, to achieve a lateral rigidity (lateral bending strength) and/or a torsional rigidity of the foundation pile according to the invention, the wall thickness thereof can be reduced considerably, since in the foundation pile according to the invention, the lateral rigidity and torsional rigidity thereof are considerably increased by means of the stabilization device, such that the rigidity of the foundation pile according to the invention is not only determined by the external geometry thereof and the wall thickness thereof. Due to the lower wall thickness of the foundation pile, steel plates with a smaller wall thickness can be used for the manufacture thereof, such that the effort for bending them and for welding the partial-cylinder segments to form foundation pile segments and for welding the foundation pile segments to the foundation pile is considerably reduced. Therefore, the foundation pile according to the invention has reduced manufacturing costs. Furthermore, due to the reduced wall thickness thereof, the foundation pile according to the invention

has a considerably reduced weight, as a result of which the transport of the partial-cylinder segments or the foundation pile segments to the installation site of the foundation pile is significantly simplified.

Lateral deformation of the foundation pile is to be understood as deformation that is directed transversely to the longitudinal axis of the foundation pile. Lateral deformation is caused by lateral forces that are exerted on the foundation pile. Lateral forces are to be understood as forces exerted on the foundation pile that have a directional component that extends perpendicular to the longitudinal axis of the foundation pile. These lateral forces can be caused by winds or water currents acting on the foundation pile.

Since compressive and/or tensile forces can be transmitted by means of the stabilization device, compressive and/or tensile forces can be transmitted by means of the stabilization device from a first inner surface section, which is connected to the stabilization device, to a second inner surface section, which is also connected to the stabilization device.

The stabilization device can also be referred to as a stabilization structure, stabilization means, stiffening structure, compression strut, tension strut or compression and/or tension strut.

The inner surface sections of the foundation pile are preferably arranged to be opposite one another, i.e. in a plan view of the foundation pile or the foundation pile segment (thus in a plan view of an end edge of the foundation pile or the foundation pile segment) the inner surface sections to which the stabilization device is connected have an angular distance of 180° . However, it is also possible for the inner surface sections to have an angular distance from one another that differs from 180° , for example between 90° and 120° , or between 120° and 150° , or between 150° and 180° . In general, the inner surface sections to which the stabilization device is connected must be angularly spaced apart from one another.

The stabilization device is preferably formed from a non-corrosive material, for example from steel and/or from carbon fibre-reinforced plastic.

The stabilization device preferably comprises at least one stabilization ring, which is arranged within the foundation pile and is connected to at least two inner surface sections of the foundation pile.

The stabilization ring preferably has a rectangular cross-sectional geometry. More preferably, the cross-section of the stabilization ring is T-shaped. More preferably, the cross-section of the stabilization ring is double-T-shaped. The stabilization ring is further preferably connected to an inner surface of the foundation pile over the entire outer circumference thereof. The stabilization ring is preferably welded to the inner surface of

the foundation pile. The stabilization ring preferably defines an angle of 360° .

The stabilization device preferably comprises at least one stabilization strut, the two ends of which are connected to the two inner surface sections of the foundation pile.

A correspondingly designed foundation pile has a particularly simple construction, such that the manufacturing costs of the correspondingly designed foundation pile are particularly low. Despite the simple design of the stabilization device as a stabilization strut, the foundation pile has increased lateral rigidity (bending strength) and increased torsional rigidity.

The stabilization strut can be straight or curved. By means of a straight stabilization strut, compressive and/or tensile forces can be transmitted particularly effectively. With a stabilization strut having a bend, the interior of the foundation pile can be used particularly effectively since the stabilization strut can be adapted to other structures within the foundation pile, for example an elevator and/or a staircase. Furthermore, the stabilization device can be used to accommodate and guide cables within the foundation pile.

The inner surface sections of the foundation pile to which the stabilization strut is connected are preferably arranged to be opposite one another.

However, it is also possible that the stabilization strut clings to the inner radius of the foundation pile, consequently at least in sections extends parallel to an inner wall of the foundation pile.

The stabilization device preferably comprises at least two stabilization struts, the components of extent of which do not extend parallel to one another, at least in some sections. The respective ends of the stabilization struts are each connected to an inner surface section of the foundation pile.

A correspondingly designed foundation pile has a further increased lateral and torsional rigidity. In particular, if the two stabilization struts have an angle of 90° to one another, forces exerted on the foundation pile from any direction can be distributed particularly advantageously within the foundation pile. This further increases the bending rigidity and the torsional rigidity of the foundation pile.

The components of extent of the at least two stabilization struts thus define a plane. The stabilization struts preferably extend perpendicular to one another. However, it is also possible that the stabilization struts enclose any angle with one another.

For example, the stabilization struts can each be straight. The stabilization struts can also each have a bend. In particular, the stabilization struts can cling to the inner wall/inner radius of the foundation pile.

The stabilization device preferably comprises at least three stabilization struts, the

components of extent of which do not extend parallel to one another in pairs. The respective ends of the stabilization struts are each connected to an inner surface section of the foundation pile.

The components of extent of the stabilization struts thus define a space. This means that the stabilization device has components of extent that are oriented in all spatial directions. For example, in the installation position of the foundation pile, if same is anchored in a subsoil and the longitudinal axis thereof is preferably oriented parallel to the direction of gravity, two of the stabilization struts extend in one plane, preferably in a horizontal plane, whereas the third stabilization strut protrudes from this plane, this stabilization strut consequently having a component of extent which is oriented perpendicular to the plane defined by the other stabilization struts.

A correspondingly designed foundation pile has a further increased rigidity, because within the height extension of the stabilization device, this counteracts lateral deformation of the foundation pile. If, for example, a wave hits a correspondingly designed foundation pile anchored in the seabed, the lateral forces exerted by the wave on the foundation pile are not only distributed within the foundation pile in the plane of the foundation pile in which the wave meets the foundation pile by means of the stabilization device within the foundation pile, but the lateral forces are also distributed to axially spaced apart areas of the foundation pile by means of the stabilization device. Consequently, lateral forces exerted on the foundation pile are more evenly distributed by means of the stabilization device in the foundation pile.

The stabilization device preferably comprises at least four stabilization struts, which do not extend parallel to one another in pairs. A first stabilization strut and a second stabilization strut define a first plane, and a third stabilization strut and a fourth stabilization strut define a second plane, wherein the first plane and the second plane enclose an angle.

Since the first plane and the second plane enclose an angle with one another, they do not extend parallel to one another. Consequently, a correspondingly designed foundation pile also has the advantage that lateral forces exerted on the foundation pile are more evenly distributed in the foundation pile by means of the stabilization device.

The stabilization struts are preferably arranged in a double-X geometry relative to one another.

The stabilization struts are preferably connected to one another.

By connecting the stabilization struts to one another, both the lateral rigidity and the torsional rigidity of the correspondingly designed foundation pile are further increased.

Furthermore, the forces exerted on the foundation pile are more evenly distributed within the foundation pile. This makes it possible for the wall thickness of the correspondingly designed foundation pile to be further reduced.

The foundation pile is preferably designed in such a way that the stabilization device comprises eight stabilization struts, wherein two stabilization struts extend axially offset and in a collinear manner relative to one another, so that four stabilization strut pairs () are formed, which do not extend parallel to one another. A first stabilization strut pair and a second stabilization strut pair define a first plane, and a third stabilization strut pair and a fourth stabilization strut pair define a second plane, wherein the first plane forms an angle with the second plane. The foundation pile further comprises a connecting device for connecting the stabilization struts to one another, wherein the connecting device comprises eight receptacles for each accepting one end of a stabilization strut, wherein the axial extents of two receptacles in each case extend parallel to one another.

Since the first plane and the second plane enclose an angle with one another, they do not extend parallel to one another. Consequently, a correspondingly designed foundation pile also has the advantage that lateral forces exerted on the foundation pile are more evenly distributed in the foundation pile by means of the stabilization device.

The stabilization strut pairs are preferably arranged in a double-X geometry relative to one another.

The respective receptacles of the connecting device can be designed, for example, as receptacle sockets into which the ends of the stabilization struts can be inserted.

The foundation pile preferably has at least two foundation pile segments, wherein the longitudinal axes of the respective foundation pile segments extend in an essentially collinear manner relative to one another.

The stabilization device is then preferably connected to inner surface sections of a foundation pile segment. In a corresponding embodiment, the stabilization device can be introduced into the foundation pile segment and connected to it before the foundation pile segment is connected to another foundation pile segment. Corresponding construction simplifies the installation of the foundation pile. According to a further possible embodiment, a stabilization device can be connected to two foundation pile segments. For example, one end of the stabilization device can be connected to a foundation pile segment, and the other end of the stabilization device can be connected to an axially adjacent foundation pile segment.

The foundation pile segments are preferably each formed from at least one partial-cylinder segment. The partial-cylinder segments are formed by bending a steel plate

along the length thereof or along the width thereof.

The two foundation pile segments are preferably connected to one another by means of the stabilization device.

By designing the foundation pile in a corresponding manner, axially adjacent foundation pile segments can support one another. Thus, lateral forces are not only transmitted through the circular weld seams between the foundation pile segments, but these are also transmitted from one foundation pile segment to an axially adjacent foundation pile segment by means of the stabilization device. This further increases the stability of the foundation pile.

The foundation pile according to the invention is preferably designed in such a way that the foundation pile segments are each formed from at least two partial-cylinder segments which are connected to one another by means of the stabilization device.

The foundation pile according to the invention is also preferably designed in such a way that longitudinal edges of adjacent partial-cylinder segments of a foundation pile segment are spaced apart from one another, such that the foundation pile has through openings between these longitudinal edges of the partial-cylinder segments.

The respective partial-cylinder segments can be connected to one another by means of the stabilization device.

In the case of the correspondingly designed foundation pile, fewer longitudinal welds are required to connect the partial-cylinder segments to one another, and fewer circular weld seams are required to connect the foundation pile segments to one another. Furthermore, the load on the foundation pile due to wind and/or waves is reduced by the through openings in the foundation pile, since wind and/or waves can enter and exit through the through openings in the foundation pile and consequently can pass through the foundation pile. The correspondingly designed foundation pile consequently provides the advantages that the foundation pile is exposed to reduced lateral forces, the wall thickness of the foundation pile can be reduced, and the total weld seam length for erecting the foundation pile is reduced.

The foundation pile preferably comprises fastening devices, which are arranged on the inside of the foundation pile, wherein the stabilization device is fastened to the fastening devices.

A correspondingly designed foundation pile offers the advantage that the forces exerted on the inside of the foundation pile by means of the stabilization device are exerted there over a larger area on the foundation pile, such that the wall thickness of the foundation pile can be further reduced.

The fastening devices can be realized in the form of fastening plates, in particular in the form of steel plates. The fastening devices advantageously cling to the inner contour of the foundation pile.

The fastening devices can be welded and/or glued to the inner surface/inner surface sections of the foundation pile. Furthermore, the fastening devices can be connected to the inner surface/inner surface sections by means of bolts, screws, etc.

The ends of the stabilization device/stabilization struts can each be connected to a fastening device. The ends of the stabilization struts can be connected to the fastening device in an articulated manner. For example, the fastening devices can each have a fastening eyelet which is connected by means of a bolt or a screw to an eyelet provided at the end of a stabilization strut.

Further advantages, details and features of the invention arise below from the explained exemplary embodiments. Brief description of the drawings:

Figure 1a: shows a schematic and perspective view of a foundation pile according to the invention according to a first embodiment of the present invention;

Figure 1b: shows a plan view of the foundation pile shown in Figure 1a;

Figure 1c: shows a plan view of a modification of the foundation pile shown in Figure 1b;

Figure 1d: shows a plan view of a further modification of the foundation pile shown in Figure 1a;

Figure 2a: shows a schematic and perspective view of a foundation pile according to the invention according to a second embodiment of the present invention;

Figure 2b: shows a plan view of the foundation pile shown in Figure 2a;

Figure 2c: shows a plan view of the foundation pile according to the second embodiment with a modified stabilization device;

Figure 3: shows a plan view of a foundation pile according to the invention according to a third embodiment of the present invention;

Figure 3: shows a plan view of a foundation pile according to the invention with a stabilization device that has been further modified;

Figure 4: shows a plan view of a foundation pile according to a fourth embodiment of the present invention;

Figure 5: shows a plan view of a foundation pile according to a fifth embodiment of the present invention;

Figure 6: shows a plan view of a foundation pile according to a sixth embodiment of the present invention;

Figure 7: shows a plan view of a foundation pile according to a seventh embodiment of the present invention;

Figure 8: shows a plan view of a foundation pile according to an eighth embodiment of the present invention;

Figure 9: shows a plan view of a foundation pile according to a ninth embodiment of the present invention;

Figure 10: shows a perspective view of a connecting device for the connecting the connecting struts to one another;

Figure 11A: shows a schematic cross-sectional illustration of part of a foundation pile according to a tenth embodiment of the present invention, in which the stabilization device is designed as a stabilization ring with a rectangular cross-section;

Figure 11B: shows a schematic cross-sectional illustration of part of a foundation pile according to an eleventh embodiment of the present invention, in which the stabilization device is designed as a stabilization ring with a T-shaped cross-section; and

Figure 11C: shows a schematic cross-sectional representation of part of a foundation pile according to a twelfth embodiment of the present invention, in which the stabilization device is designed as a stabilization ring with a double-T-shaped cross-section.

Figure 1a shows a schematic and perspective view of a foundation pile 10 according to the invention according to a first embodiment of the present invention, and Figure 1b shows the foundation pile 10 shown in Figure 1a in a plan view, consequently in a plan view of an end edge 13 of the foundation pile 10. The foundation pile 10 is placed in a subsoil B, wherein the subsoil B can also be the seabed B. The foundation pile 10 can be brought into or driven into the subsoil B by means of impact hammers and/or vibration rams. As a result, a lower part of the foundation pile 10 is anchored in the subsoil B, and an upper part of the foundation pile 10 is arranged above the architecture B. A further structure, for example a transition piece (not shown) and/or a nacelle (not shown) of a wind power plant, can be attached to the upper area of the foundation pile 10.

The foundation pile 10 comprises a stabilization device 30 which, in the exemplary embodiment shown, is designed as a stabilization strut 31. The stabilization strut 31 is connected to two fastening devices 50, which are fastened to mutually opposite inner surface sections 11 of the foundation pile 10. In the embodiment shown, the inner surface sections 11 are arranged to be opposite one another and have an angular spacing of 180°. The stabilization strut 31 is designed to absorb compressive forces and to absorb tensile forces, such that the stabilization strut 31 counteracts both lateral deformation and torsional deformation of the foundation pile 10.

Of course, it is also possible for the stabilization device 10 to be designed, for example, as a stabilization line 10 that is designed to only absorb tensile forces. Even with a corresponding design of the stabilization device 10, this counteracts lateral and torsional deformation of the foundation pile 10.

Due to the stabilization strut 31 arranged within the foundation pile 10 and connected to the inner surface sections 11 of the foundation pile 10, forces exerted on the foundation pile 10 by the action of wind and/or waves are distributed within the foundation pile 10. The foundation pile 10 according to the invention thus has an increased lateral rigidity and an increased torsional rigidity. For this reason, the wall thickness of the foundation pile 10 can be significantly reduced, since the lateral rigidity and torsional rigidity thereof are increased considerably by means of the stabilization device 30. Thus, it is not only the external geometry thereof and the wall thickness thereof that determine the lateral rigidity and the torsional rigidity of the foundation pile 10.

The foundation pile 10 is usually composed of a large number of foundation pile segments 20 (see Figures 8 and 9), the end edges of which are connected to one another. This connection is usually made by welding. The respective foundation pile segments 20 are produced by bending steel plates, wherein the opposing side edges are connected to one another, wherein this connection is also realized by welding by means of a longitudinal weld seam or also by means of clamps. However, a foundation pile segment 20 can also be produced from two or more partial-cylinder segments (see Figure 8).

The fastening devices 50 can be fastened to the inside of the foundation pile 10 by means of gluing and/or welding and/or screwing the fastening devices 50 to the inner surface sections 11 of the foundation pile 10. The fastening devices 50 are designed as fastening plates 50 in the exemplary embodiment shown. By means of the fastening plates 50, the forces exerted by means of the stabilization strut 31 on the inner surface sections 11 of the foundation pile 10 are distributed over a larger surface area, such that the wall thickness of the foundation pile 10 can thereby be reduced.

In Figure 1c, a slightly modified foundation pile 10 according to the first embodiment is shown in plan view. The foundation pile 10 shown in Figure 1c differs from the foundation pile 10 shown in Figures 1a and 1b in that the angular distance between the fastening devices 50 corresponds to approximately 135° . Even with a corresponding positioning of the fastening plates 50 on the inner surface of the foundation pile 10, an increase in the torsional rigidity and the lateral rigidity of the foundation pile 10 is achieved. Of course, it is also possible for the angular distance between the fastening devices 50 to assume a different value. It is also within the scope of the invention that the fastening devices 50

are not arranged in a common horizontal plane in the installation position of the foundation pile 10. The fastening devices 50 can also be axially spaced apart from one another, such that the stabilization strut 31 connected to the fastening devices 50 also has a component of extent in the axial direction of the foundation pile 10.

In Figure 1d, a further modification of the foundation pile 10 according to the first embodiment is shown in plan view. The angular spacing of the fastening devices 50 is 90° , and the fastening strut 10 is not straight but has a bend. However, the rest of the structure of the foundation pile 10 shown in Figure 1d is, identical to the structure of the foundation pile 10 shown in Figures 1a to 1c.

Figure 2a shows a foundation pile 10 according to a second embodiment of the present invention in a perspective view, and Figure 2b shows the foundation pile 10 shown in Figure 2a in plan view. The stabilization device 30 comprises two stabilization struts 31, 32, which are connected to one another in the exemplary embodiment shown. However, it is also possible that the stabilization struts 31, 32 are not connected to one another. The respective ends of the stabilization struts 31, 32 are connected to four fastening plates 50. In the embodiment shown, the fastening plates 50 are in the installation position of the foundation pile 10 in a common horizontal plane. However, the present invention is not limited to a corresponding arrangement of the stabilization device 30 in the foundation pile 10. The fastening plates 50 can also be axially spaced apart from one another, such that the stabilization struts 31, 32 then also have components of extent in the axial direction of the foundation pile 10.

In Figure 2c, a modification of the foundation pile 10 is shown according to the second embodiment. The foundation pile 10 comprises only two fastening devices 50 which are arranged to be opposite one another. Furthermore, the stabilization struts 31, 32 of the stabilization device 30 each have a bend and cling to the inner surface of the foundation pile 10. It can also be seen that the fastening plates 50 are each connected to two ends of the stabilization struts 31, 32. By designing the stabilization struts 31, 32 in a corresponding manner, the interior area of the foundation pile 10 can be better utilized.

In Figure 3, a foundation pile 10 according to a third embodiment of the present invention is shown in plan view. In this foundation pile 10, the stabilization device has four stabilization struts 31-34, which are connected to the inner wall of the foundation pile 10 by four fastening devices 50. The fastening devices 50 each have an angular spacing of 90° from one another, wherein two fastening devices 50 directly adjacent to one another are connected by means of a stabilization strut 31-34. As a result, a relatively large free space is achieved in the interior of the foundation pile 10, which has increased usability.

The fastening devices 50 can of course be axially spaced apart from one another in the installation position of the foundation pile 10, such that the fastening struts 31-34 then not only extend in a horizontal plane of the foundation pile 10 but also have components of extent that are directed parallel to the longitudinal axis 12 of the foundation pile 10.

Figure 4 shows a foundation pile 10 according to a fourth embodiment is shown in plan view. The stabilization device 30 comprises eight stabilization struts 31-38, the respective ends of which are connected to opposite inner surface sections 11 of the foundation pile 10. It can be seen from Figure 4 that the respective stabilization struts 31-38 are connected to one another by means of a connecting device 40 shown schematically.

Figure 5 shows a foundation pile 10 according to a fifth embodiment in plan view. The foundation pile segment 20 shown is composed of eight partial-cylinder segments 24. The respective partial-cylinder segments 24 are connected to one another by means of the stabilization device 30. Also in the case of the foundation pile 10 shown in Figure 5, the respective connecting struts 31-38 are connected to one another by means of a connecting device 40. The respective partial-cylinder segments 24 are radially spaced apart from one another, such that a through opening 14 of the foundation pile 10 is formed between two partial-cylinder segments 24. With a corresponding design of the foundation pile 10, wind and/or waves can enter and exit the foundation pile 10, thereby reducing the load on the foundation pile 10.

Figure 6 shows a foundation pile 10 according to a sixth embodiment in plan view. In the case of the foundation pile 10 according to the sixth embodiment, the respective partial-cylinder segments 24 have a radius of curvature that is smaller than a radius of curvature of the envelope of the foundation pile 10. A corresponding design of the foundation pile 10 means that it has increased lateral rigidity and also increased torsional rigidity. The rest of the structure of the foundation pile 10 shown in Figure 6 is identical to the foundation pile 10 shown in Figure 4.

In the case of the foundation piles 10 shown in Figures 4, 5 and 6, the stabilization devices 30 each have eight stabilization struts 31-38. However, the stabilization devices 30 can also be designed in such a way that the connecting struts 31-38 running parallel to one another are each viewed as a connecting strut, such that the foundation piles 10 shown in Figures 4 to 6 each have only four stabilization struts. In all of the foundation piles 10 shown in Figures 4 to 6, the connection points of the stabilization struts 31-38 with the inside of the foundation pile 10 can be axially spaced apart from one another such that, in the installed position of the foundation pile 10, the stabilization device 30 or the stabilization struts 31-38 have components of extent that run parallel to the longitudinal

axis 12 of the foundation pile 10.

In a schematic, perspective illustration, Figure 8 shows a foundation pile 10 according to an eighth embodiment of the present invention. The foundation pile 10 is composed of four foundation pile segments 20 in that the respective foundation pile segments 20 are connected to one another at the contact edges thereof by means of a circular weld seam. The uppermost foundation pile segment 20 is composed of two partial-cylinder segments 24, which are connected to one another by means of a stabilization device 30. The partial-cylinder segments 14 are radially spaced apart from one another, such that through openings 14 of the foundation pile 10 are formed between the longitudinal edges 21 of the respective partial-cylinder segments 24.

In the embodiment shown, the stabilization device 30 has two stabilization struts, the ends of which are each connected to a fastening plate 50. In the installation position of the foundation pile 10, the stabilization struts 31, 32 extend in the horizontal plane. Of course, it is also possible that the fastening plates 50 are fastened to the inner surface of the foundation pile 10 in such a way that, in the installation position of the foundation pile 10, the stabilization struts 31, 32 have components of extent that run parallel to the longitudinal axis 12 of the foundation pile 10.

It can be seen from Figure 8 that foundation pile segments 20, that each have at least one through opening 14, are axially enclosed by foundation pile segments 20 that have no through openings 14. As a result, the foundation pile segments 20, which are composed of at least two partial-cylinder segments 24, are also stabilized by the axially adjacent foundation piles 20 in addition to the stabilization by means of the stabilization device 30.

In Figure 9, a foundation pile 10 is shown according to a ninth embodiment. It can be seen that the foundation pile segments 20 axially adjacent to one another are each formed from a partial-cylinder segment 24, wherein longitudinal edges 21 of the respective partial-cylinder segments 24 are spaced apart from one another such that the foundation pile 10 formed in this way has through openings 14. The stabilization device 30 connects two foundation pile segments 20 axially adjacent to one another and stabilizes them relative to one another. It can also be seen from Figure 9 that the through openings 14 of foundation pile segments 20 axially adjacent to one another have an angular spacing of 180°.

Figure 10 shows a connecting device 40 for connecting stabilization struts 31-38 with respect to one another. In the exemplary embodiment shown, the connecting device 40 has eight receptacles 41 or receptacle sockets 41 into which the stabilization struts 31-

38 (see Figures 4, 5 and 6) can be inserted and connected to the connecting device 40. The arrangement of the receptacles 41 of the connecting device 40 is chosen geometrically such that the stabilization struts 30-38 inserted into the receptacles 41 have a double-X geometry. A corresponding design of the stabilization device 30 provides particularly high lateral and torsional rigidity for the foundation pile 10.

Figure 11A shows a schematic cross-sectional illustration of part of a foundation pile 10 according to a tenth embodiment of the present invention, in which the stabilization device 30 is designed as a stabilization ring 39_1 with a rectangular cross-section. The stabilization ring 39_1 is connected to the inner surface 11 of the foundation pile 10 over the entire outer circumference thereof. The stabilization ring 39_1 defines an angle of 360°.

Figure 11B shows a schematic cross-sectional illustration of part of a foundation pile 10 according to an eleventh embodiment of the present invention, in which the stabilization device 30 is designed as a stabilization ring 39_2 with a T-shaped cross-section. The stabilization ring 39_2 is connected to the inner surface 11 of the foundation pile 10 over the entire outer circumference thereof. The stabilization ring 39_2 defines an angle of 360°.

Figure 11C shows a schematic cross-sectional illustration of part of a foundation pile 10 according to a twelfth embodiment of the present invention, in which the stabilization device 30 is designed as a stabilization ring 39_3 with a double-T-shaped cross-section. The stabilization ring 39_3 is connected to the inner surface 11 of the foundation pile 10 over the entire outer circumference thereof. The stabilization ring 39_3 defines an angle of 360°.

List of Reference Symbols

10	Foundation pile
11	Inner surface section (of the foundation pile)
12	Longitudinal axis (of the foundation pile)
13	End edge (of the foundation pile)
14	Through opening (of the foundation pile)
20	Foundation pile segment
21	Longitudinal edge/sheet metal edge/material edge (of the foundation pile segment)
23	End edge (of the foundation pile segment)
24	Partial-cylinder segment (of the foundation pile segment)
30	Stabilization device
31-38	Stabilization strut
39_1	Stabilization ring
39_2	Stabilization ring (with T-shaped cross-section)
39_3	Stabilization ring (with double-T-shaped cross-section)
40	Connecting device
41	Receptacle/receptacle socket/socket (of the connecting device)
50	Fastening device/fastening plate
B	Subsoil/seabed

FUNDERINGSPÆL TIL ET VINDENERGIANLÆG

Patentkrav

1. Funderingspæl (10), hvor funderingspælen (10) omfatter en stabiliseringsanordning (30; 31-38, 39_1, 39_2, 39_3), der er placeret inden for funderingspælen (10) og er forbundet med mindst to inderfladeafsnit (11) af funderingspælen (10), hvor der ved hjælp af stabiliseringsanordningen (30; 31-38, 39_1, 39_2, 39_3) kan overføres tryk- og/eller trækkræfter, således at stabiliseringsanordningen (30; 31-38, 39_1, 39_2, 39_3) modvirker en lateral deformation og/eller en torsionsdeformation af funderingspælen (10), **kendetegnet ved**, at stabiliseringsanordningen (30; 31-38) omfatter mindst én stabiliseringsstiver (31-38), hvis to over for hinanden liggende ender er forbundet med to inderfladeafsnit (11) af funderingspælen (10).
2. Funderingspæl (10) ifølge krav 1, **kendetegnet ved**, at stabiliseringsanordningen (30; 31-38, 39_1, 39_2, 39_3) omfatter en stabiliseringsring (39_1, 39_2, 39_3), der er placeret inden for funderingspælen (10) og er forbundet med mindst to inderfladeafsnit (11) af funderingspælen (10).
3. Funderingspæl (10) ifølge et af de foregående krav, **kendetegnet ved** følgende træk:
 - stabiliseringsanordningen (30; 31-38) omfatter mindst to stabiliseringsstivere (31-38), hvis udstrækningskomponenter i det mindste afsnitvist ikke forløber parallelt med hinanden; og
 - de respektive ender af stabiliseringsstiverne (31-38) er forbundet med hver et inderfladeafsnit (11) af funderingspælen (10).
4. Funderingspæl (10) ifølge et af de foregående krav, **kendetegnet ved** følgende træk:
 - stabiliseringsanordningen (30; 31-38) omfatter mindst tre stabiliseringsstivere (31-38), hvis udstrækningskomponenter i hvert enkelt tilfælde parvist ikke forløber parallelt med hinanden; og
 - de respektive ender af stabiliseringsstiverne (31-38) er forbundet med hver et inderfladeafsnit (11) af funderingspælen (10).

5. Funderingspæl (10) ifølge et af de foregående krav, **kendetegnet ved** følgende træk:

- stabiliseringsanordningen (30; 31-38) omfatter fire stabiliseringsstivere (31-38), der i hvert enkelt tilfælde parvist ikke forløber parallelt med hinanden; og
- en første stabiliseringsstiver (31-38) og en anden stabiliseringsstiver (31-38) udspænder et første plan, og en tredje stabiliseringsstiver (31-38) og en fjerde stabiliseringsstiver (31-38) udspænder et andet plan, hvor det første plan og det andet plan danner en vinkel.

6. Funderingspæl (10) ifølge et af de foregående krav, **kendetegnet ved** at stabiliseringsstiverne (31-38) er forbundet med hinanden.

7. Funderingspæl (10) ifølge et af de foregående krav, **kendetegnet ved** følgende træk:

- stabiliseringsanordningen (30; 31-38) omfatter otte stabiliseringsstivere (31-38);
- i hvert enkelt tilfælde forløber to stabiliseringsstivere (31-38) aksialt forskudt i forhold til og kollineært med hinanden, således at der dannes fire stabiliseringsstiverpar, der ikke forløber parallelt med hinanden;
- et første stabiliseringsstiverpar og et andet stabiliseringsstiverpar udspænder et første plan, og et tredje stabiliseringsstiverpar og et fjerde stabiliseringsstiverpar udspænder et andet plan, hvor det første plan sammen med det andet plan danner en vinkel; og
- funderingspælen (10) omfatter desuden en forbindelsesanordning (40) til forbindelse af stabiliseringsstiverne (31-38), hvor forbindelsesanordningen (40) omfatter otte holdere (41) til i hvert enkelt tilfælde at optage en ende af en stabiliseringsstiver (31-38), hvor de aksiale udstrækninger af i hvert enkelt tilfælde to holdere (41) forløber parallelt med hinanden.

8. Funderingspæl (10) ifølge et af de foregående krav, **kendetegnet ved**, at funderingspælen (10) omfatter mindst to funderingspælssegmenter (20), hvor længdeakserne af de respektive funderingspælssegmenter (20) i det væsentlige forløber kollineært med hinanden.

9. Funderingspæl (10) ifølge krav 8, **kendetegnet ved**, at de to funderingspælssegmenter (20) er forbundet med hinanden ved hjælp af

stabiliseringsanordningen (30; 31-38, 39_1, 39_2, 39_3).

10. Funderingspæl (10) ifølge krav 8 eller 9, **kendetegnet ved**, at funderingspælssegmenterne (20) hver er dannet af mindst to delcylindersegmenter (24), der er forbundet med hinanden ved hjælp af stabiliseringsanordningen (30; 31-38, 39_1, 39_2, 39_3).

11. Funderingspæl (10) ifølge krav 10, **kendetegnet ved**, at længdekanter (21) af delcylindersegmenter (24), der ligger op til hinanden, på funderingspælssegmentet (10) har en indbyrdes afstand, således at funderingspælen (10) mellem disse længdekanter (21) af delcylindersegmenterne (24) har gennemgangsåbninger (14).

12. Funderingspæl (10) ifølge et af de foregående krav, **kendetegnet ved**, at funderingspælen (10) omfatter fastgørelsesanordninger (50), der er placeret på indersiden af funderingspælen (10), hvor stabiliseringsanordningen (30) er fastgjort på fastgørelsesanordningerne (50).

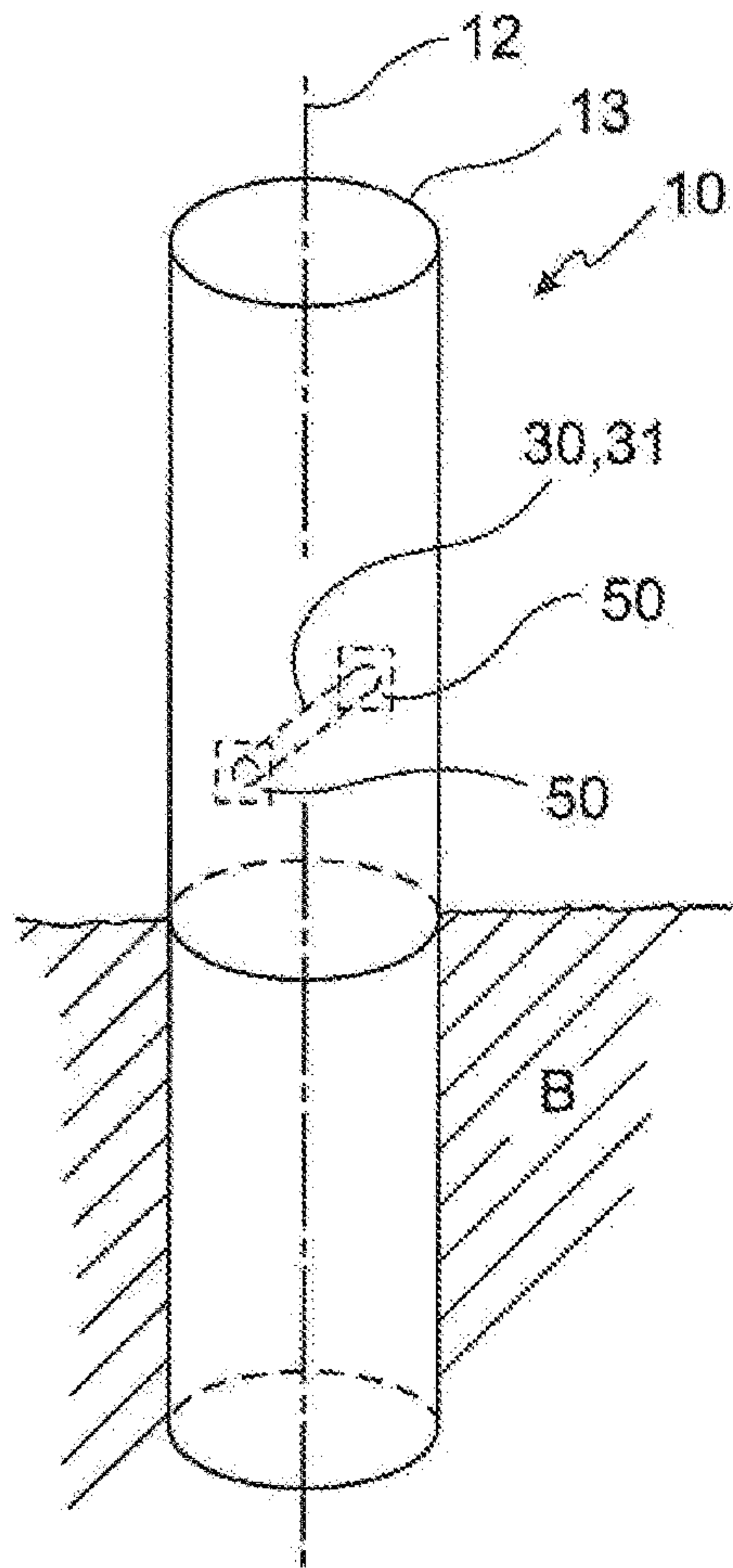


Fig. 1a

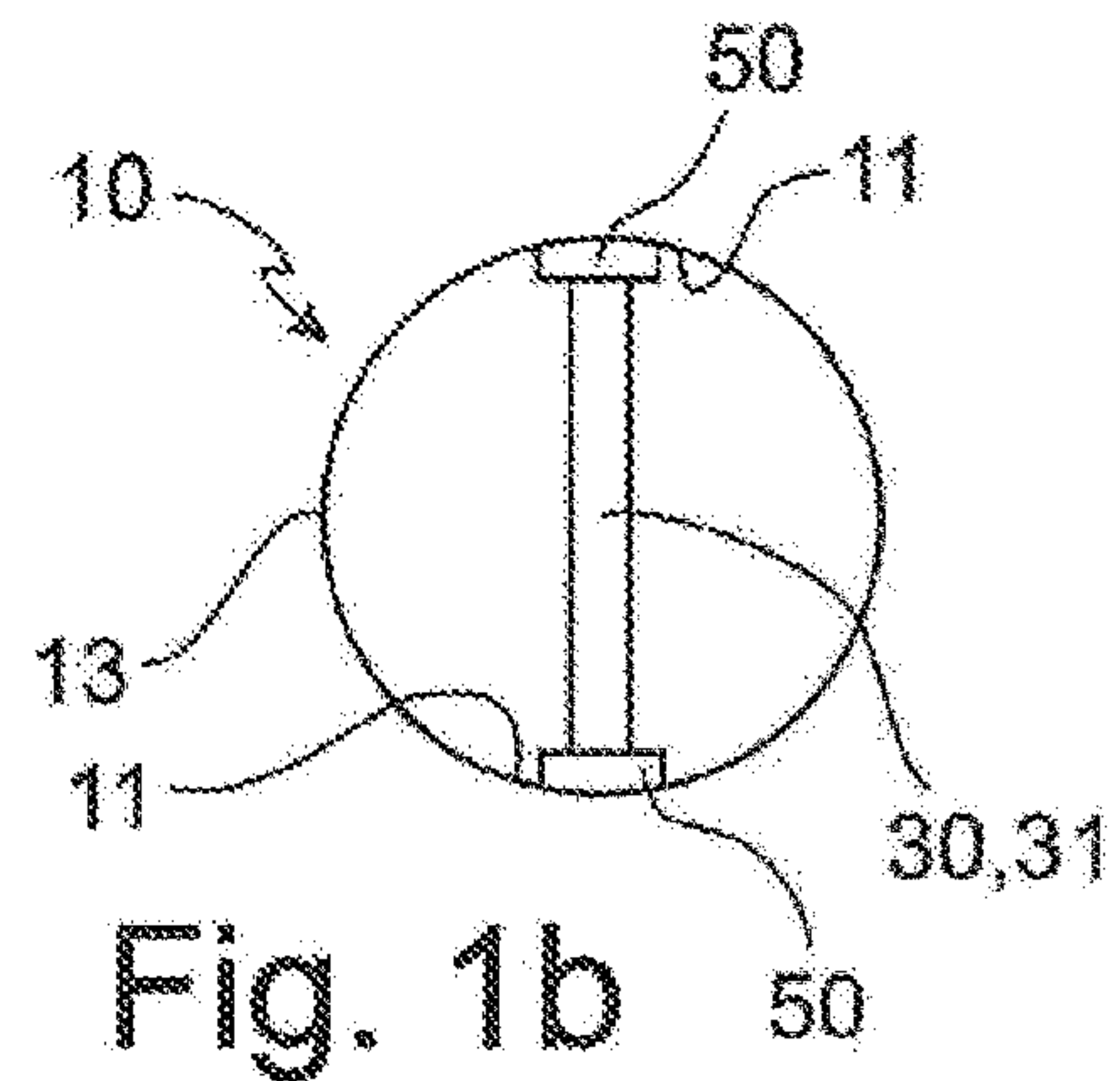


Fig. 1b

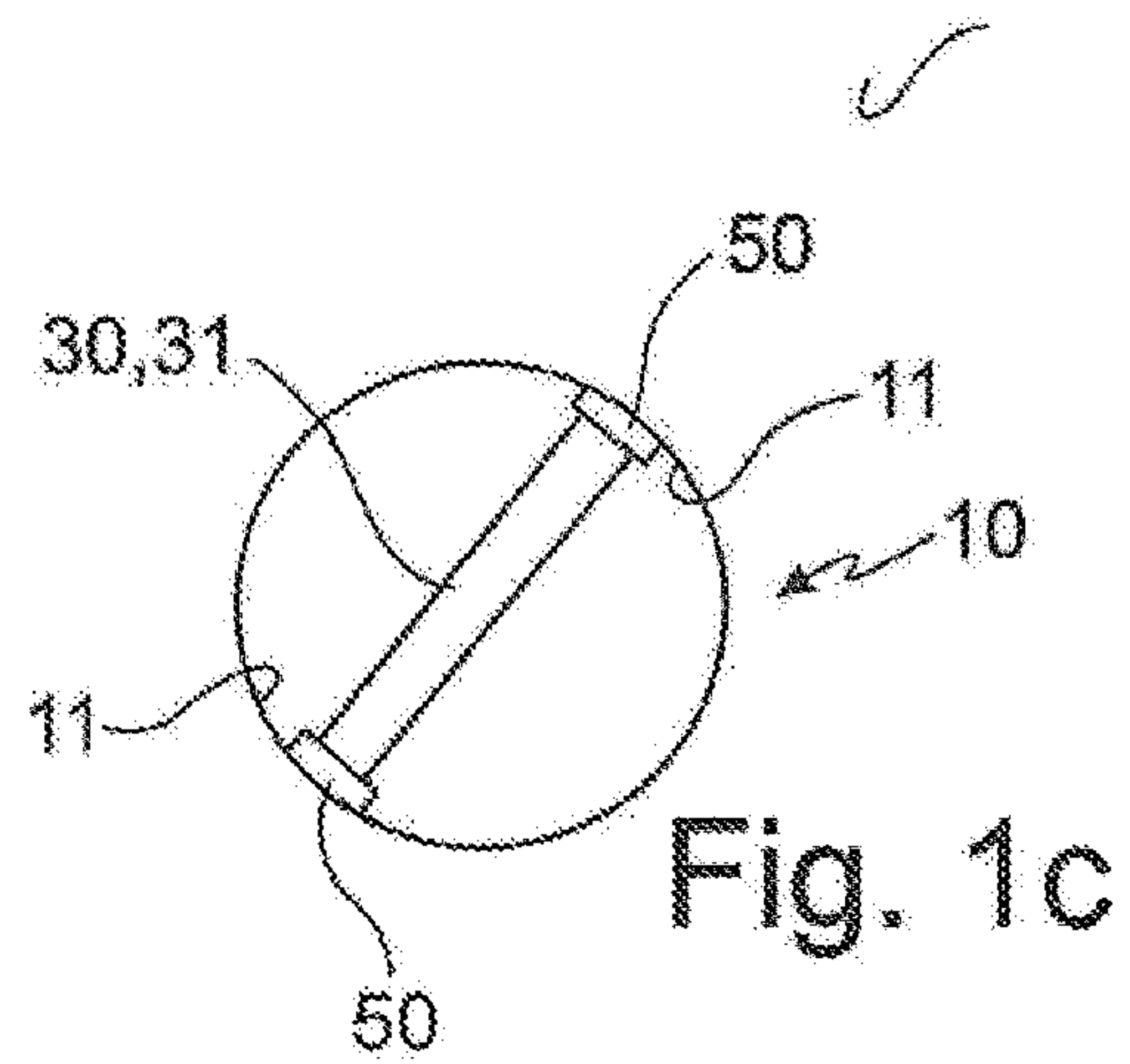


Fig. 1c

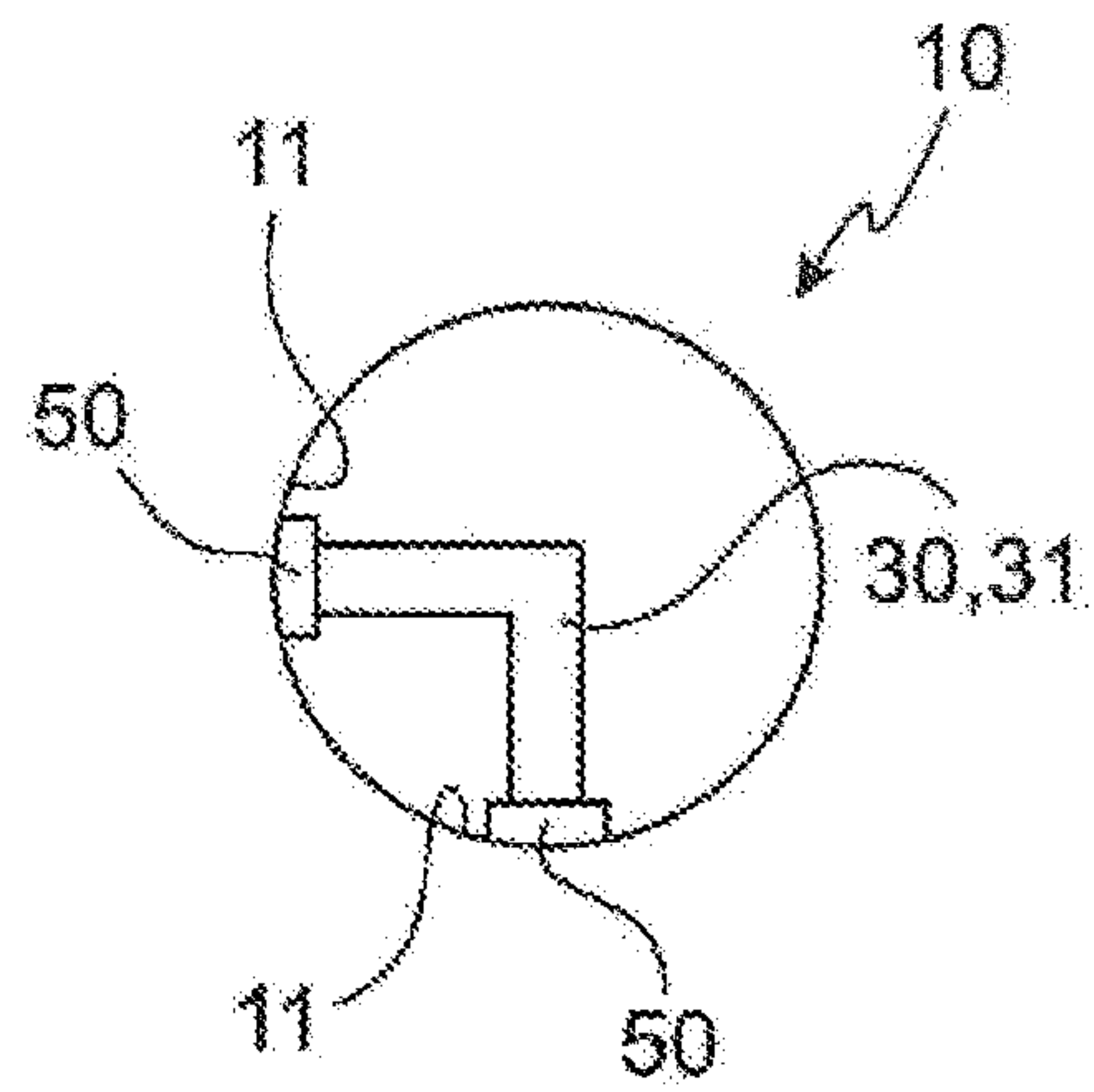


Fig. 1d

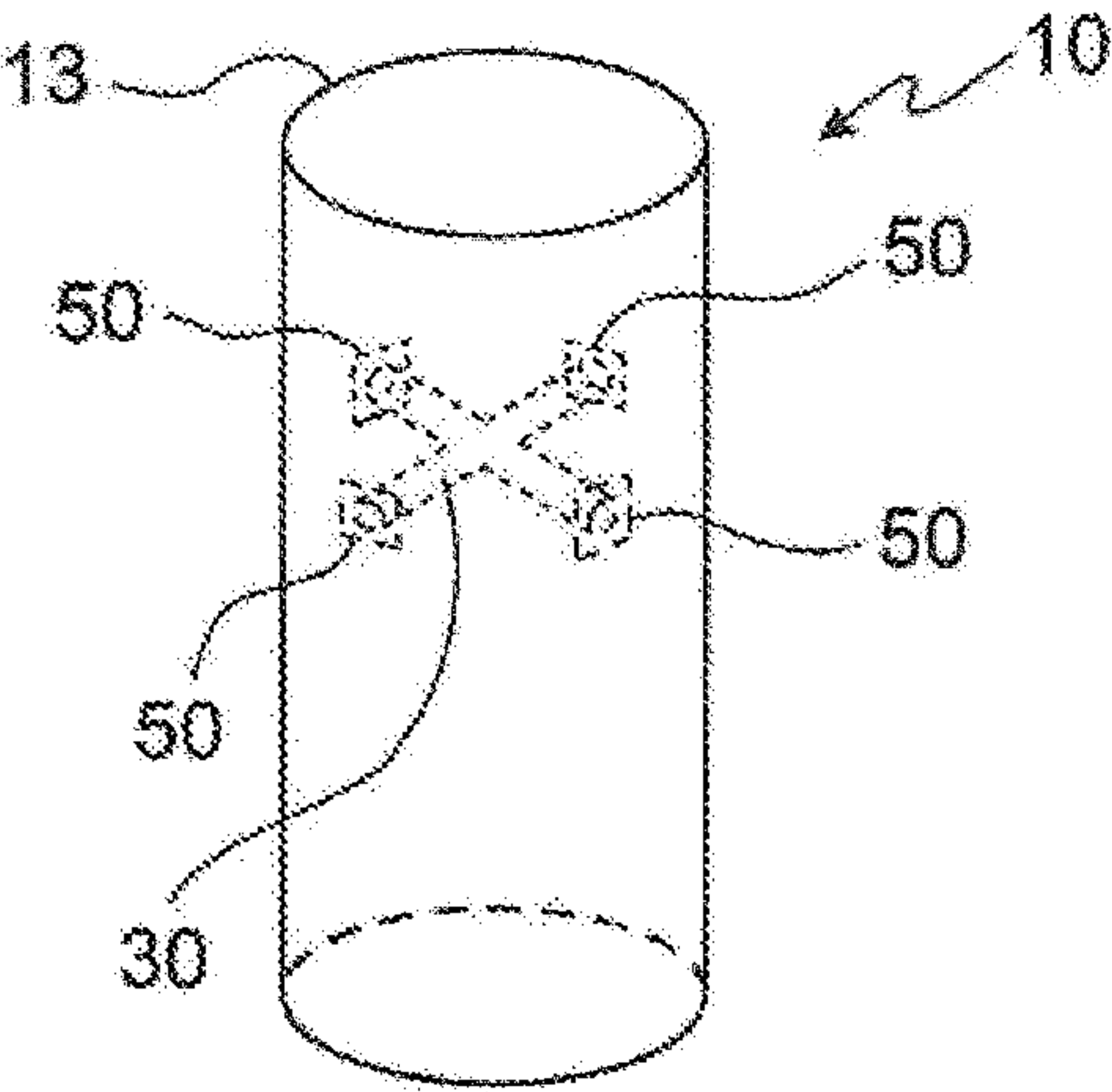


Fig. 2a

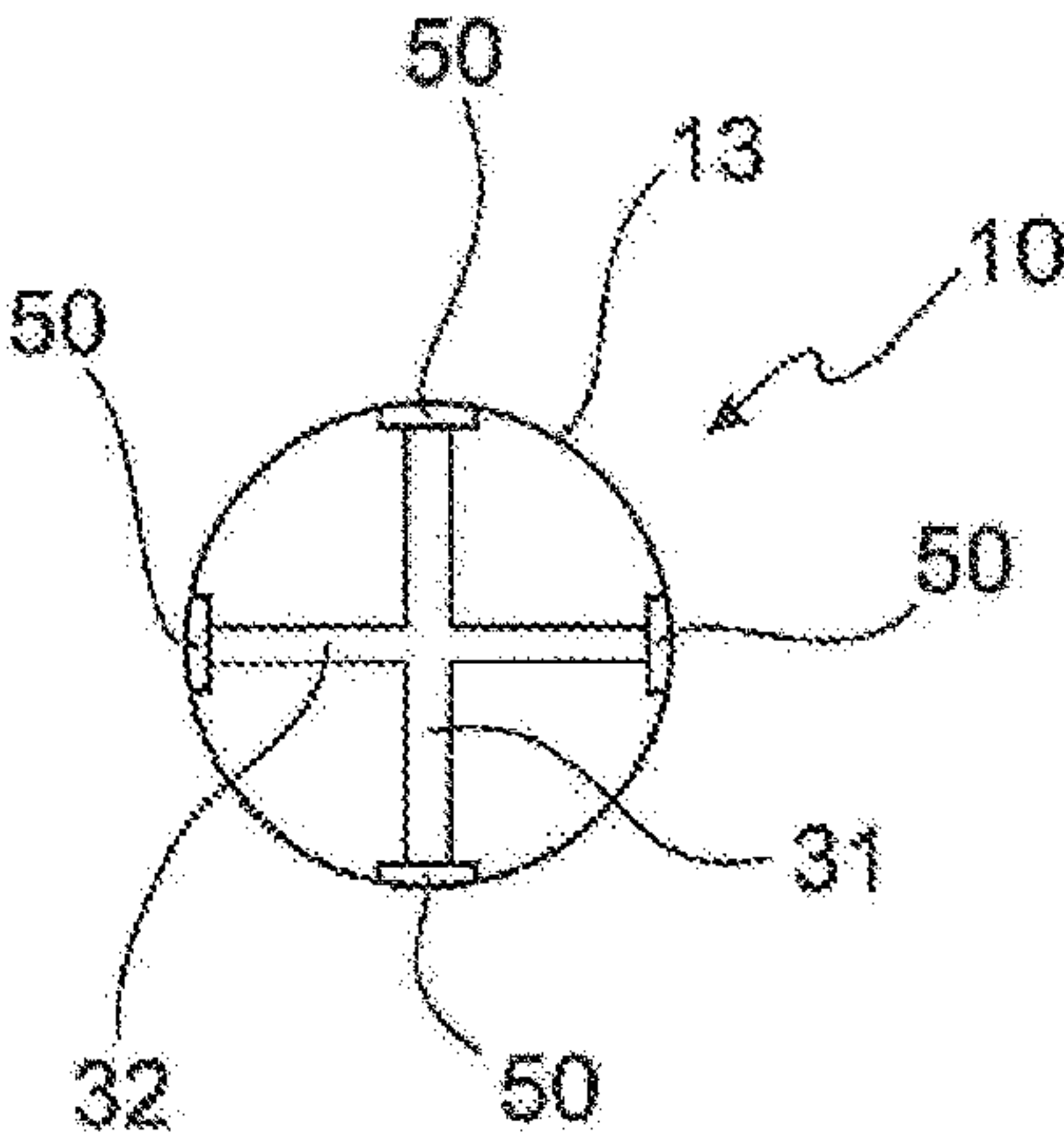


Fig. 2b

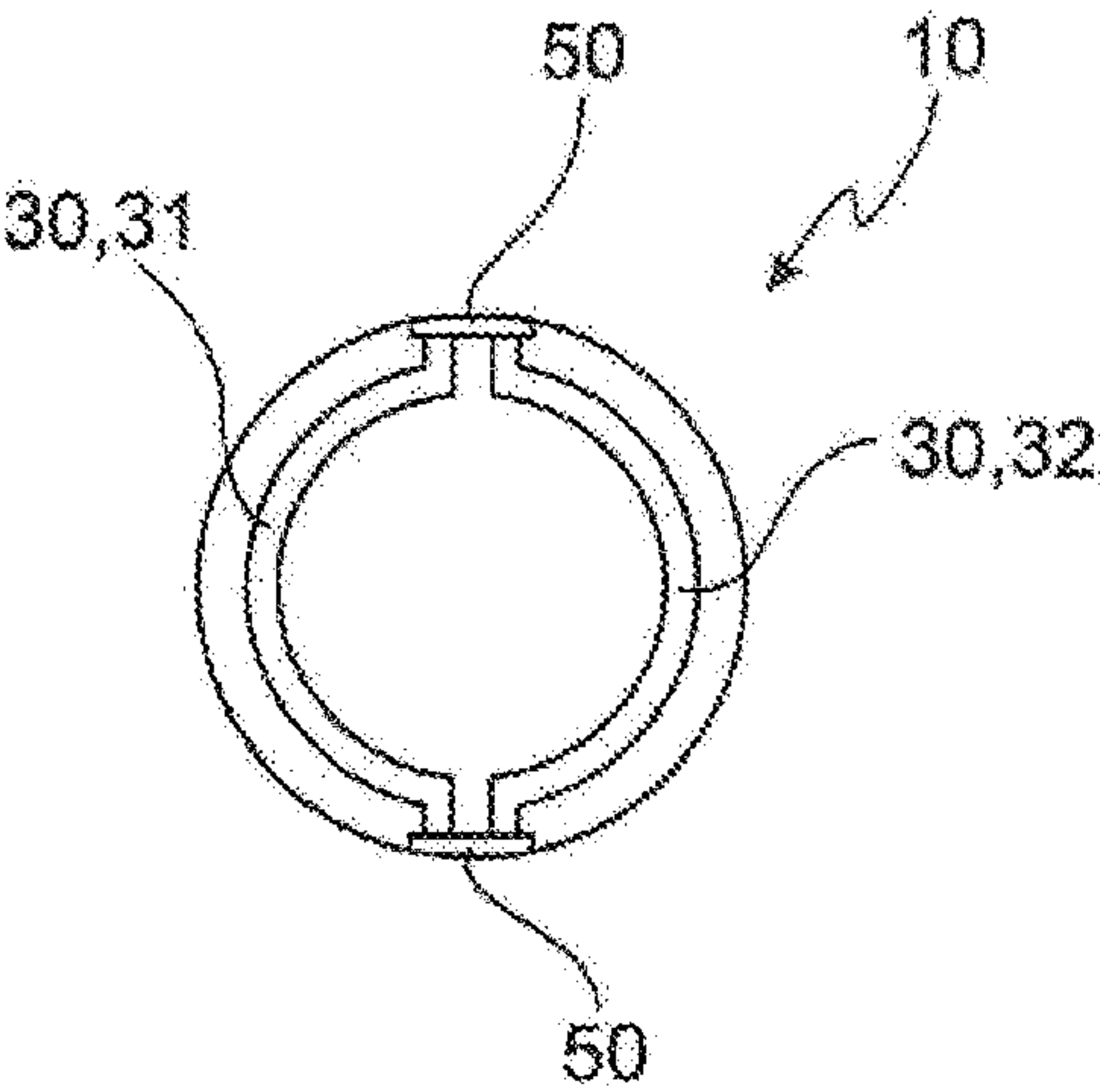


Fig. 2c

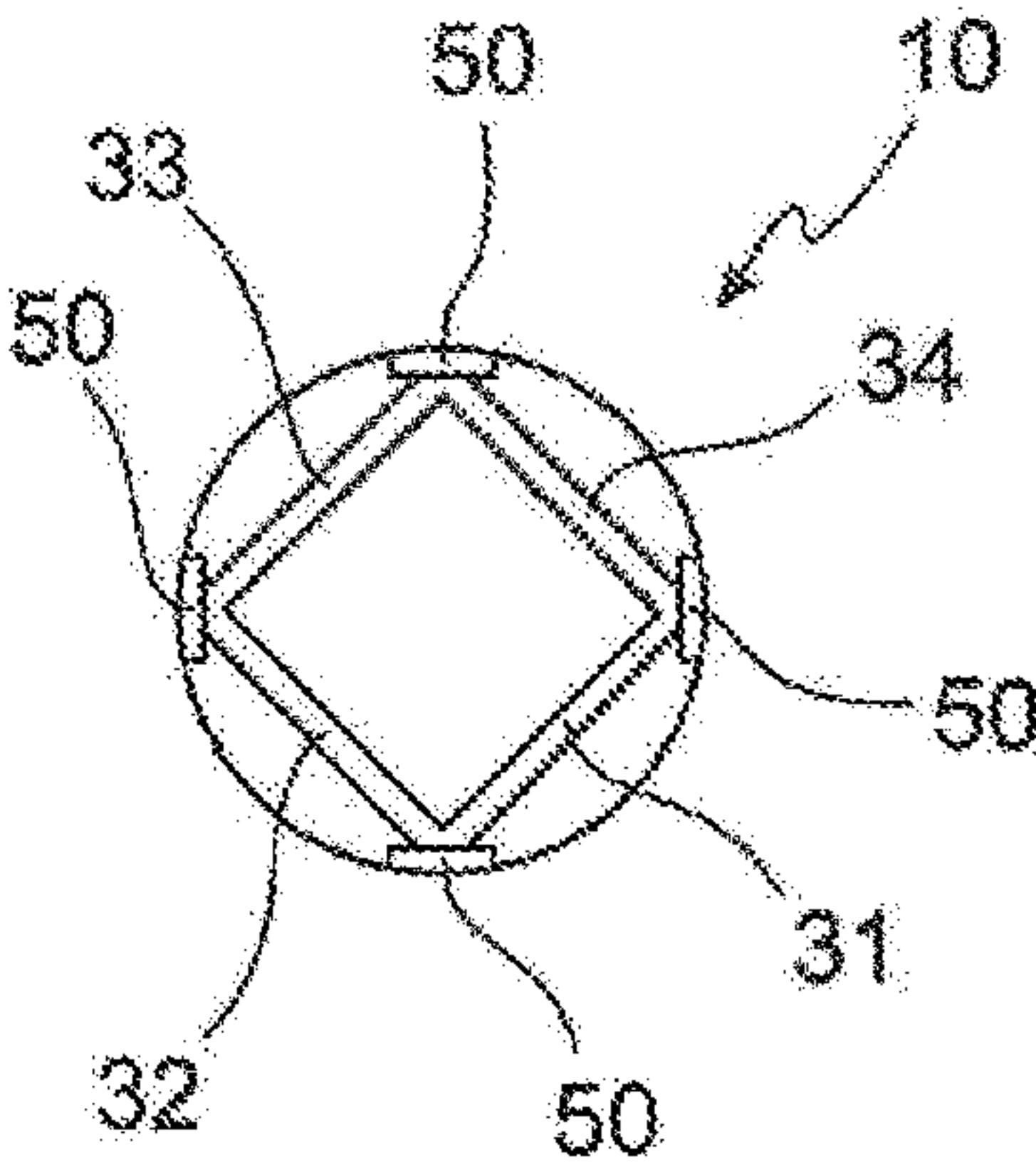


Fig. 3

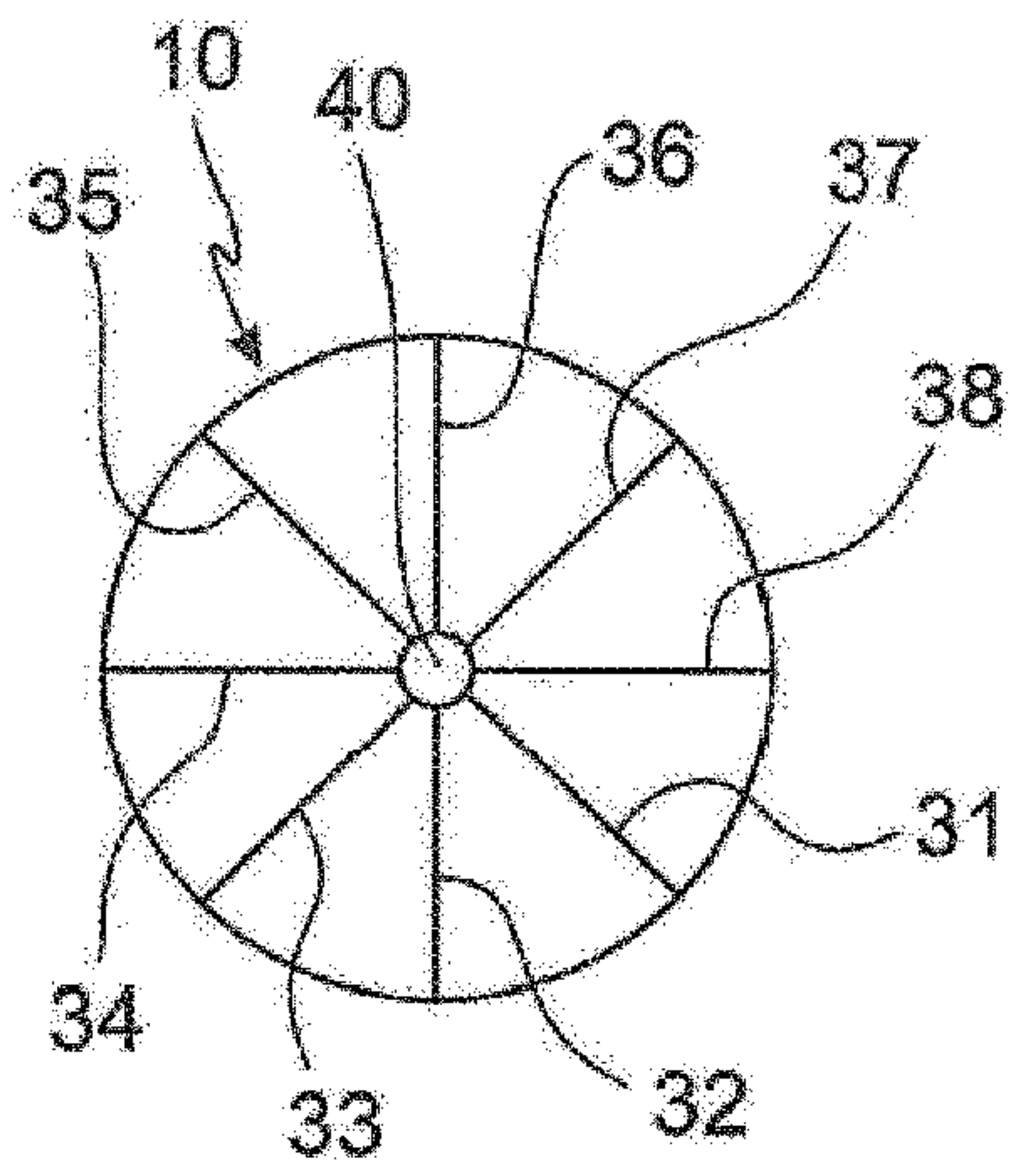


Fig. 4

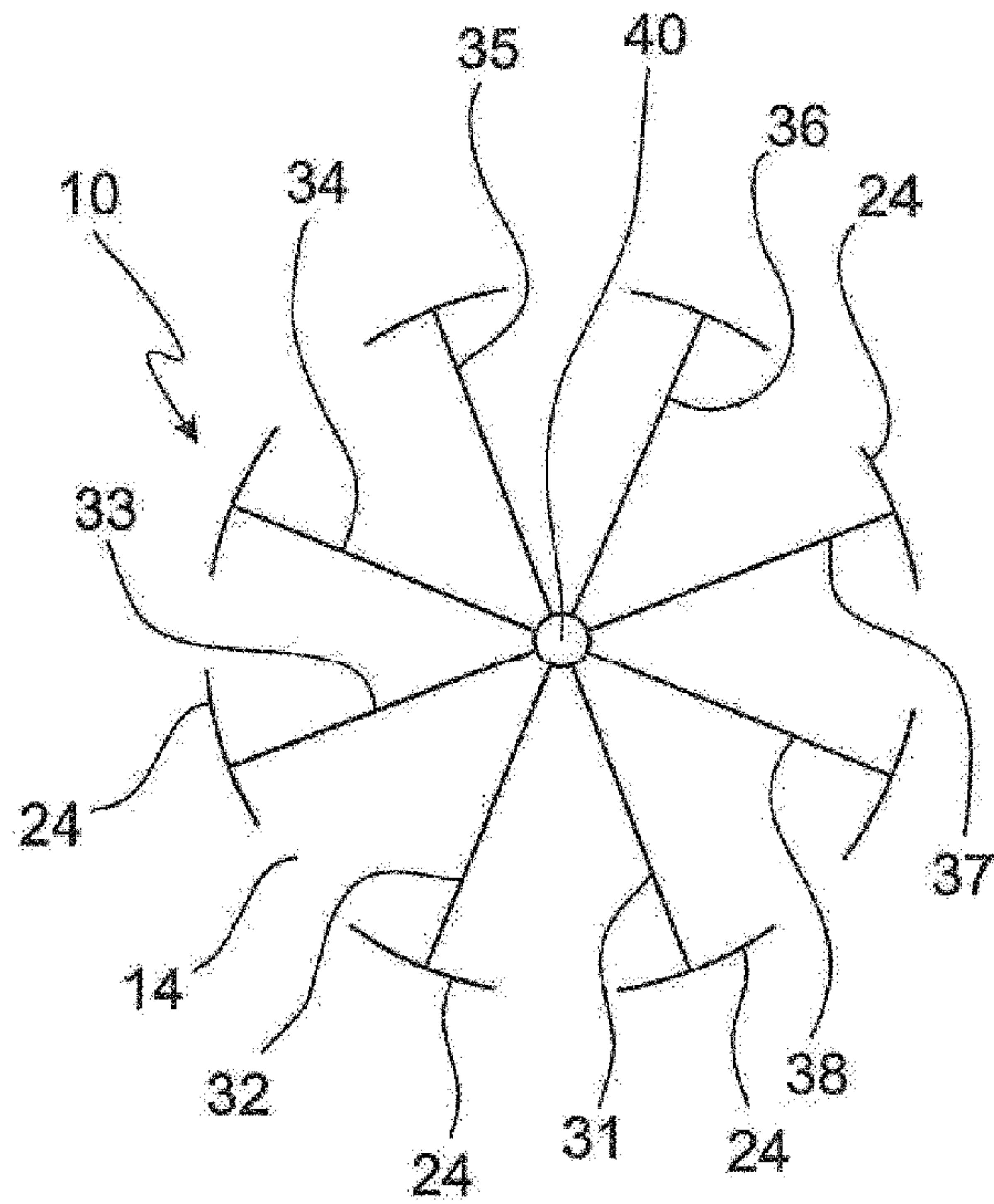


Fig. 5

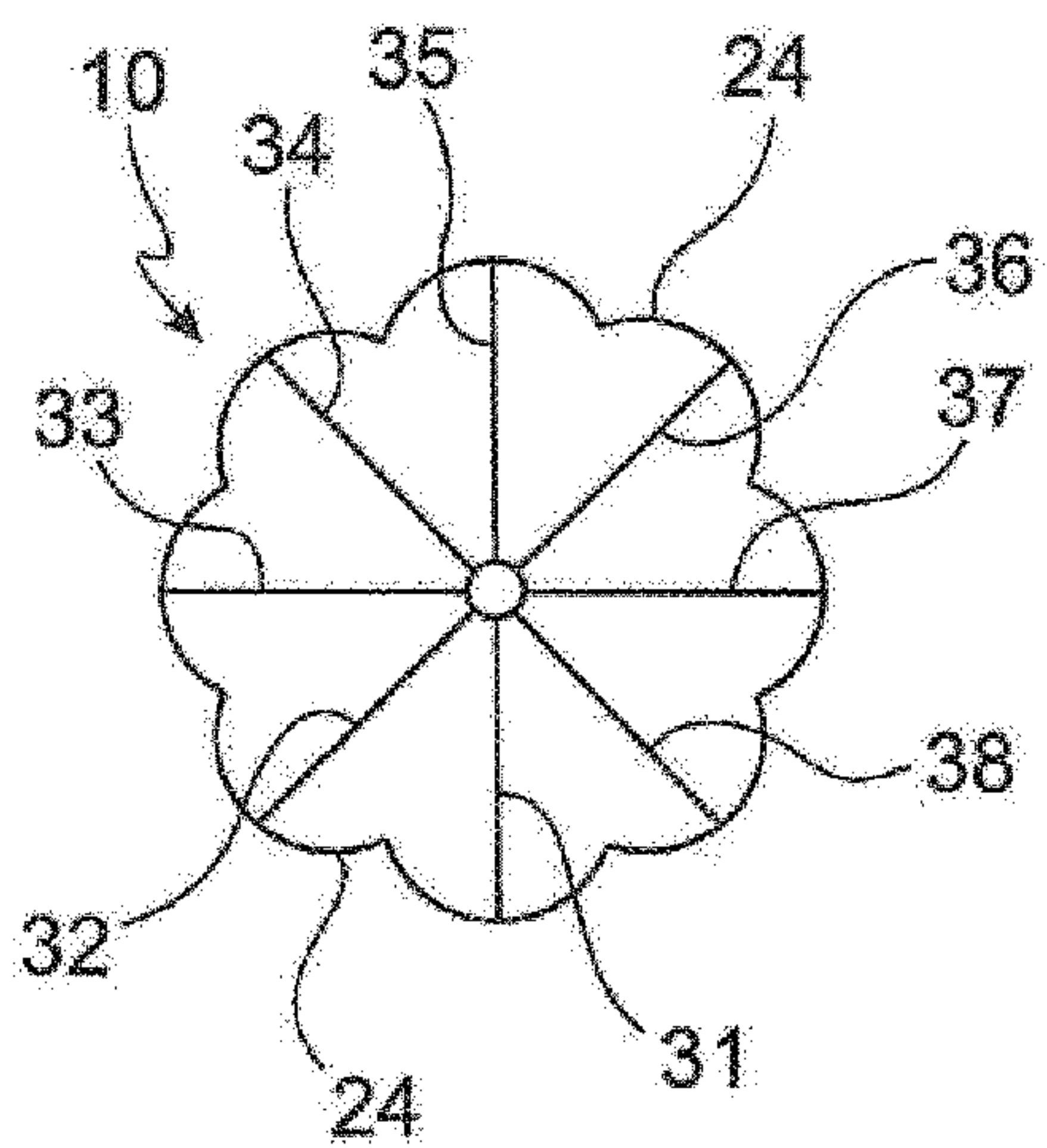


Fig. 6

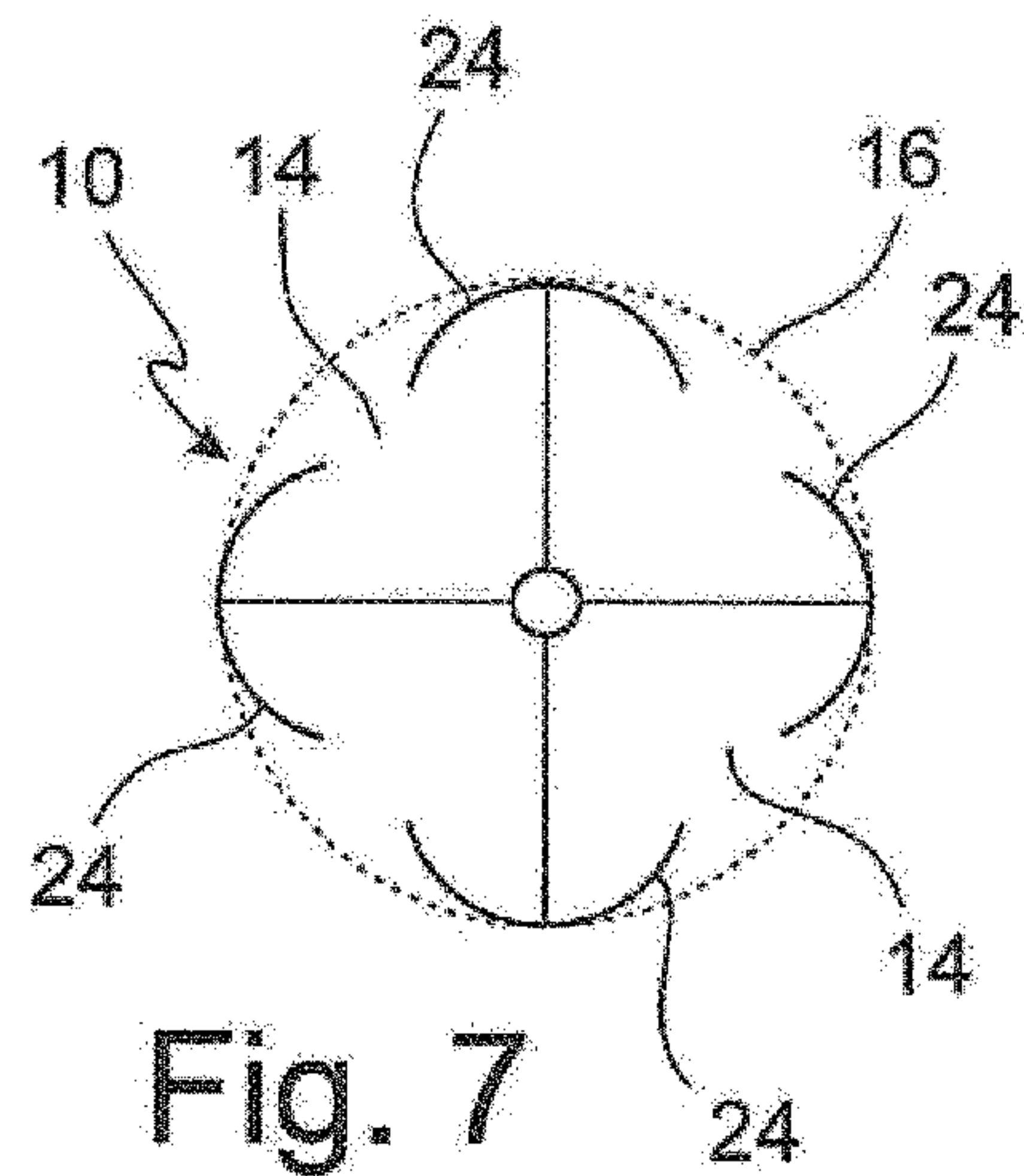


Fig. 7

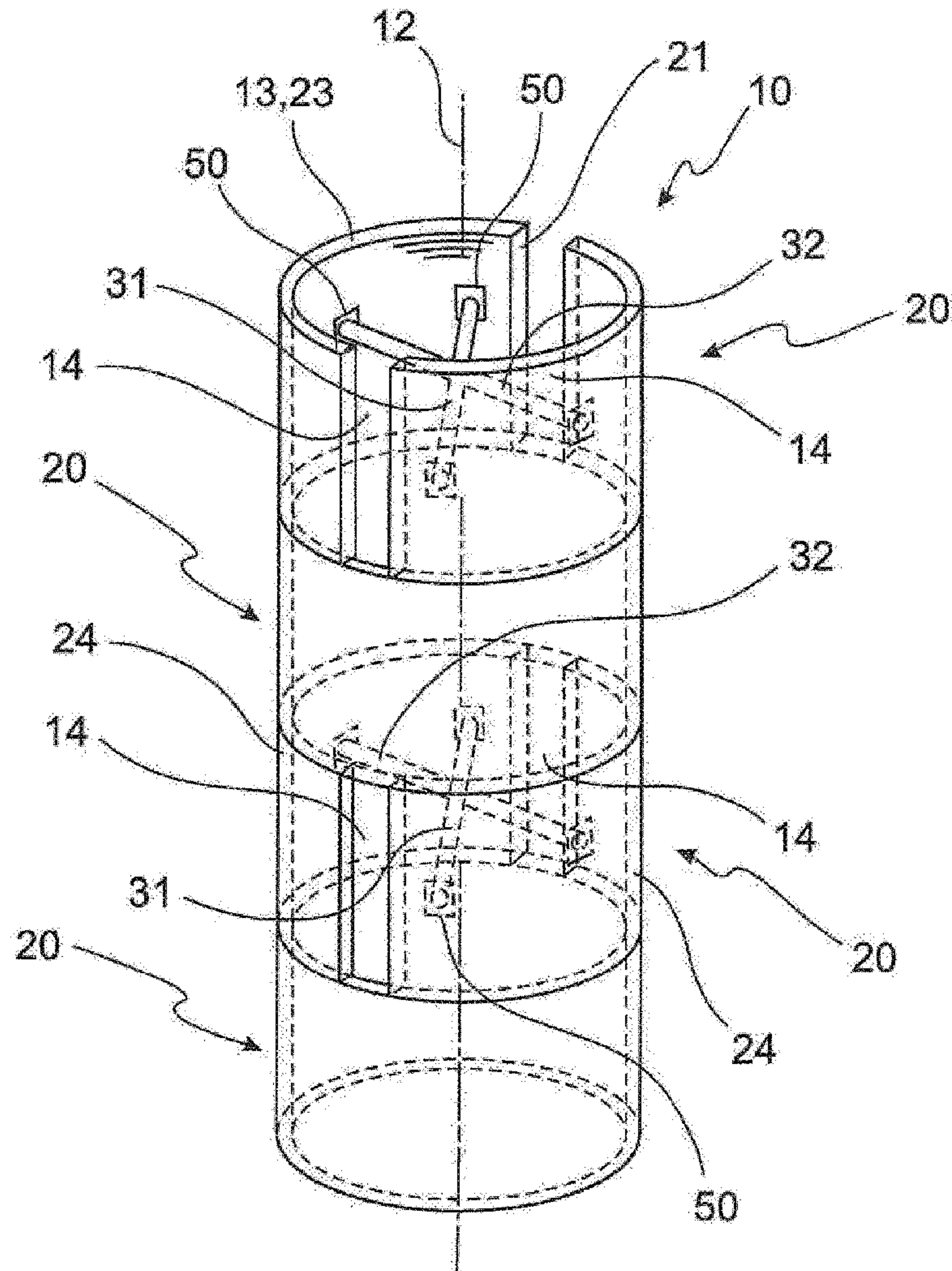


Fig. 8

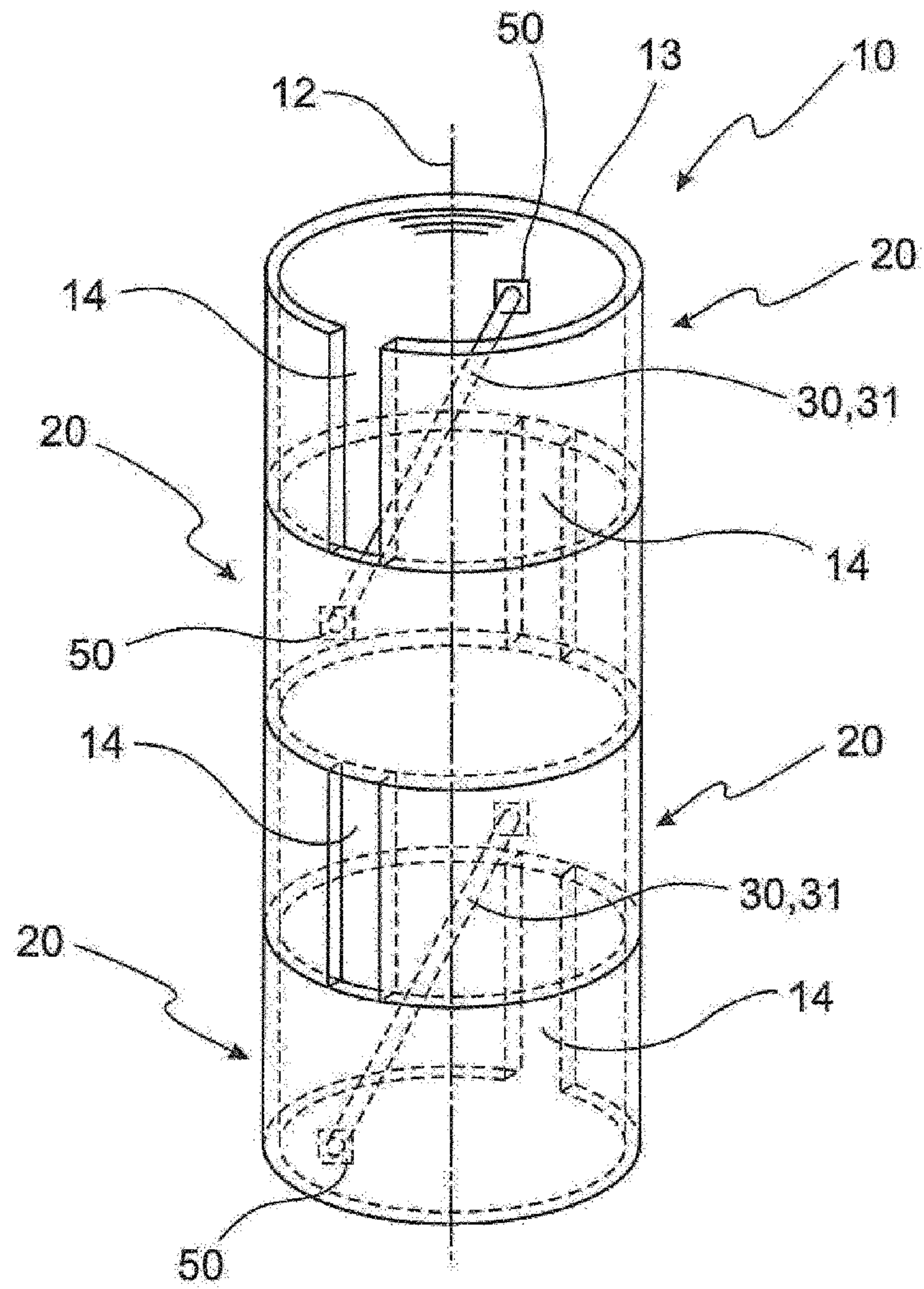


Fig. 9

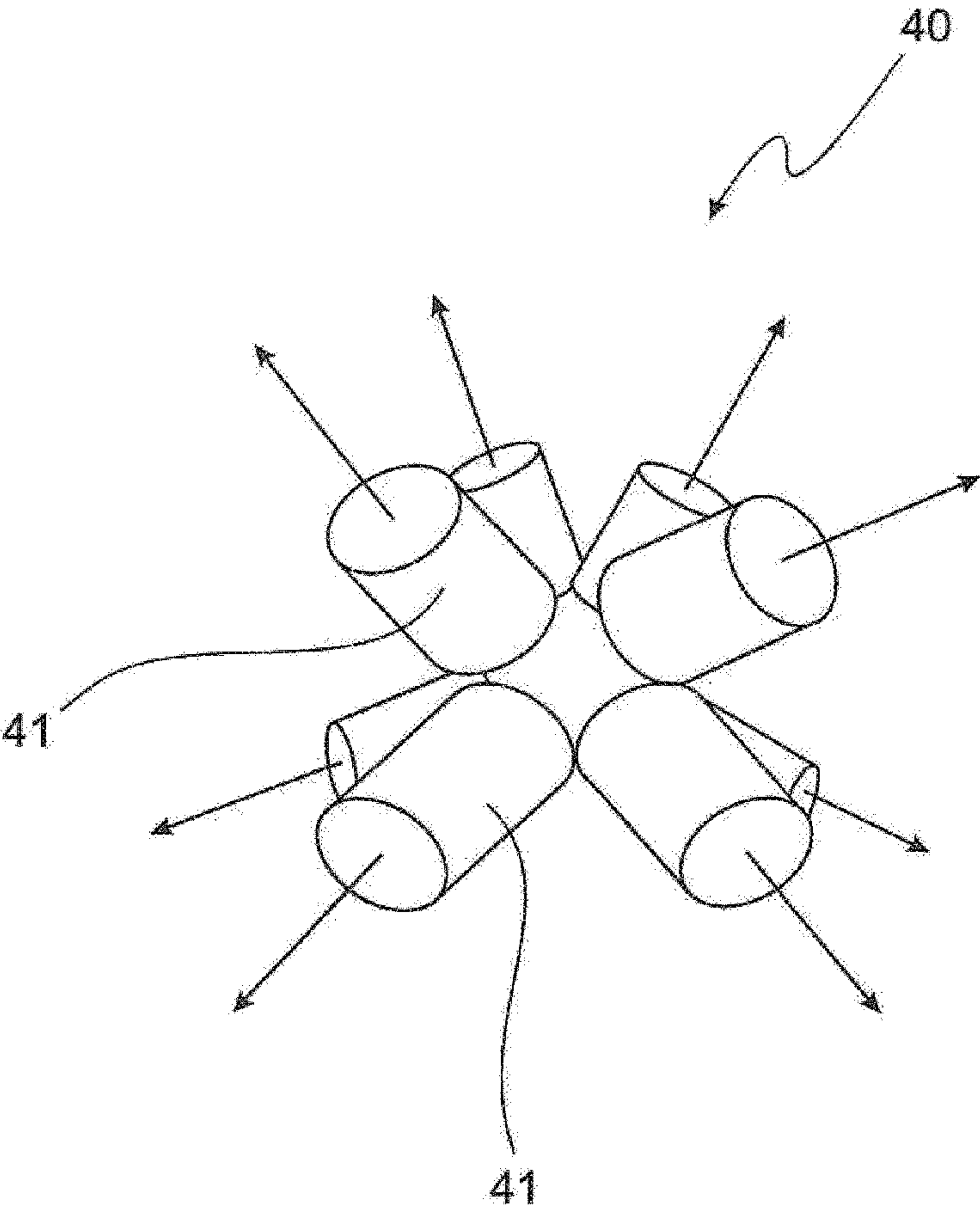


Fig. 10

