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(54) VARIABLE GEOMETRY TURBINE

(76) Inventor: **Khimani Mohiki**, Huddersfield (GB)

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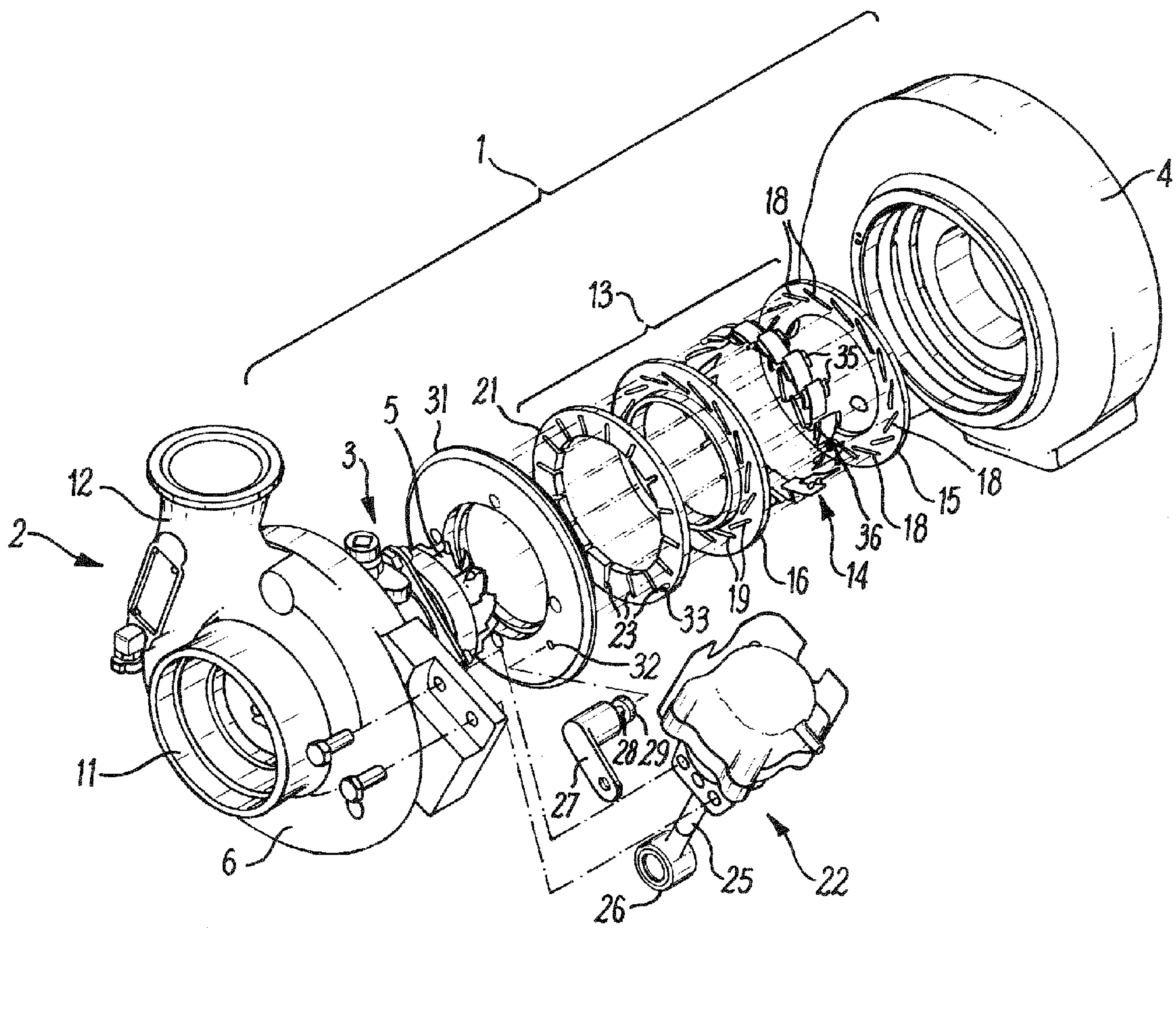
(57) **ABSTRACT**

A variable geometry turbine for a turbocharger has a plurality of vanes disposed in an inlet passageway of a turbine housing outboard of the turbine wheel. The vanes are movable so as to adjust the effective cross-section area of the inlet between a first position in which the area of the inlet is a minimum and a second position in which the area of the inlet is a maximum. The movement of one end of the vanes is supported by a plurality of first guide tracks, such as slots, defined in a guide member. A vane actuator such as, for example a unison ring, effects movement of the vanes. The vane actuator has a plurality of actuation tracks (e.g. slots) for engagement with the vanes and is rotatably disposed in the housing. When it rotates the vane actuator induces sliding translation of the vanes relative to the first guide tracks in a first direction and sliding translation of the vanes relative to the actuation tracks in a second direction so as to adjust the cross-section area of the inlet. The swirl angle changes between the first and second positions.



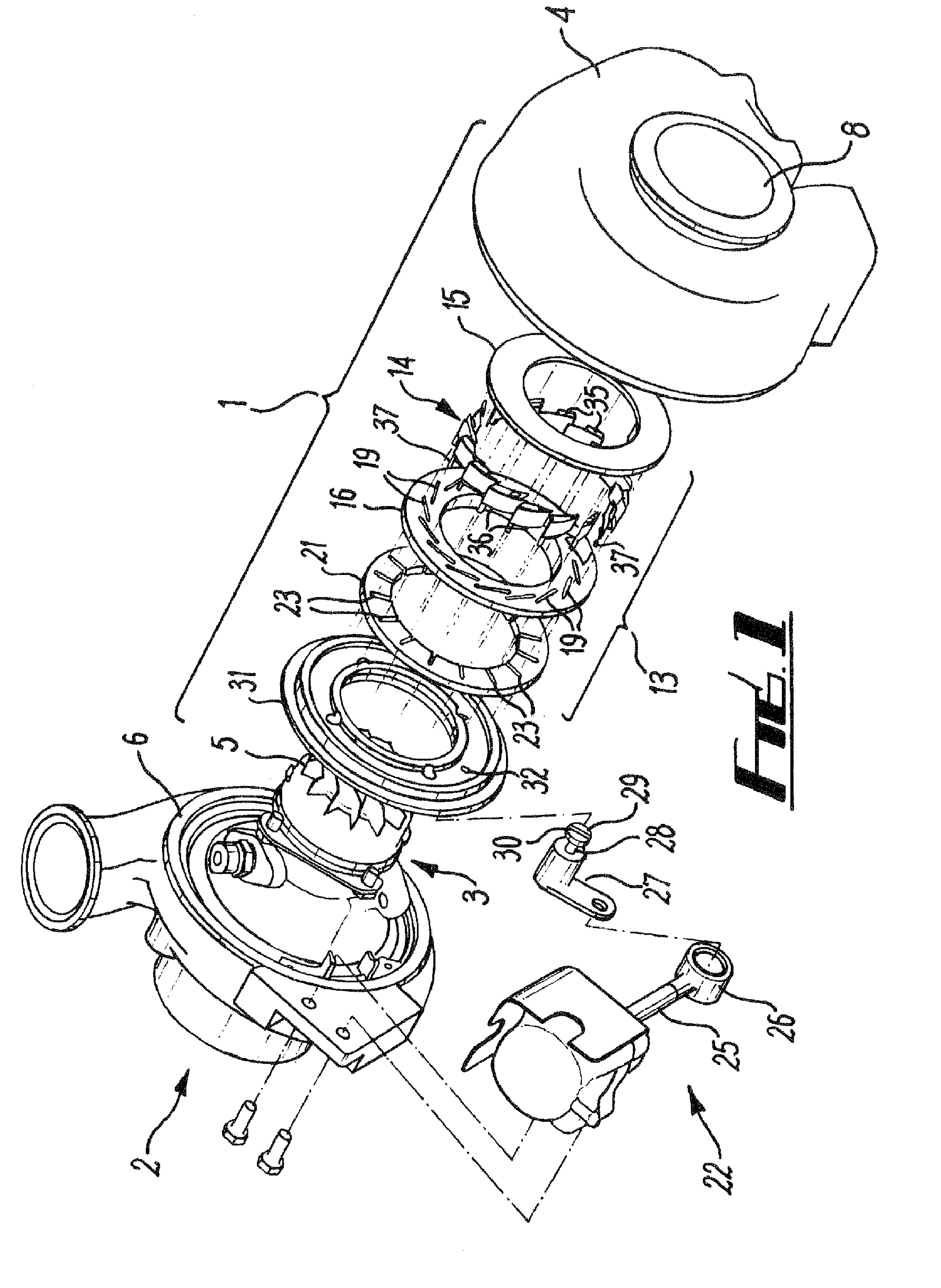

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FIG. 1

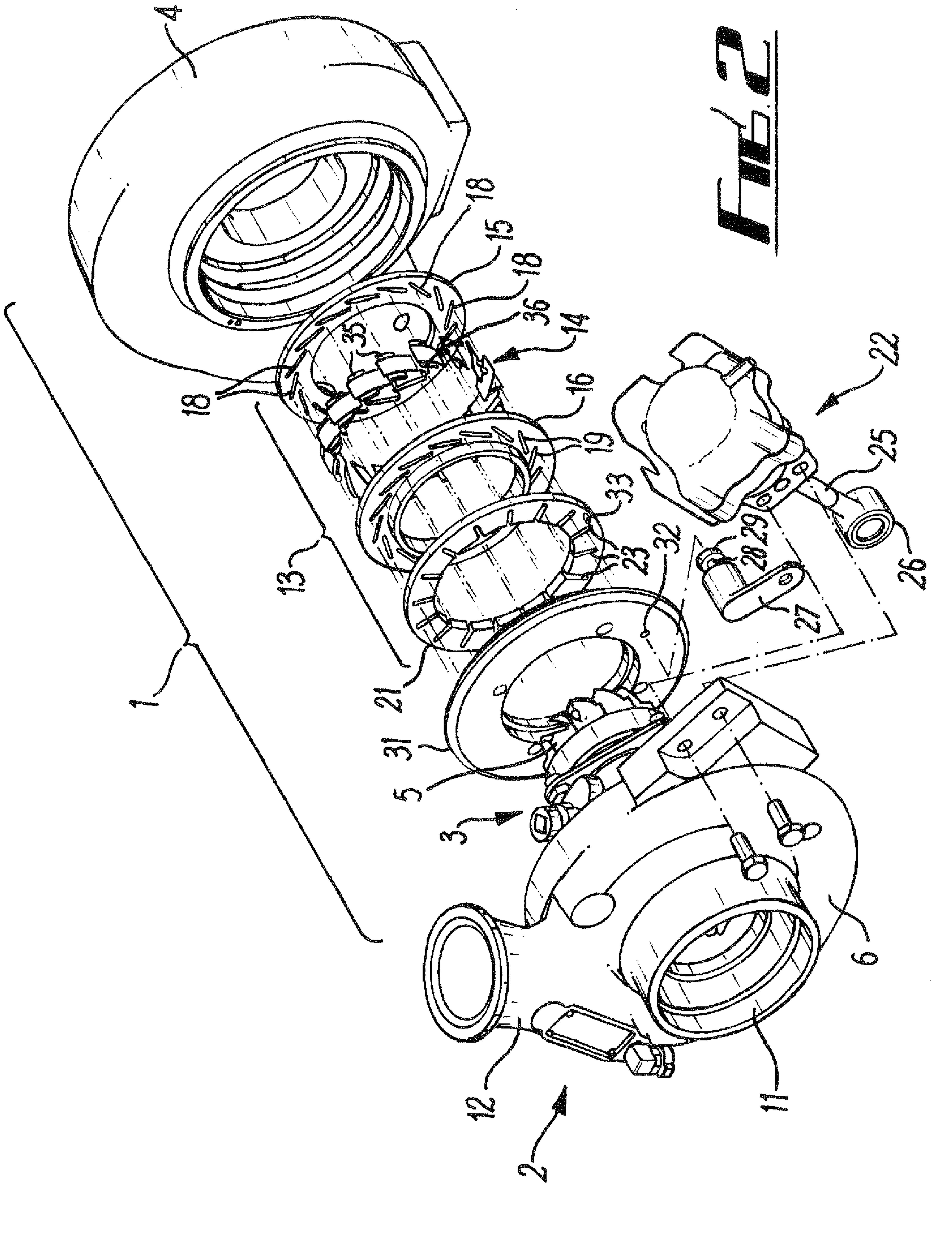

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FIG. 2

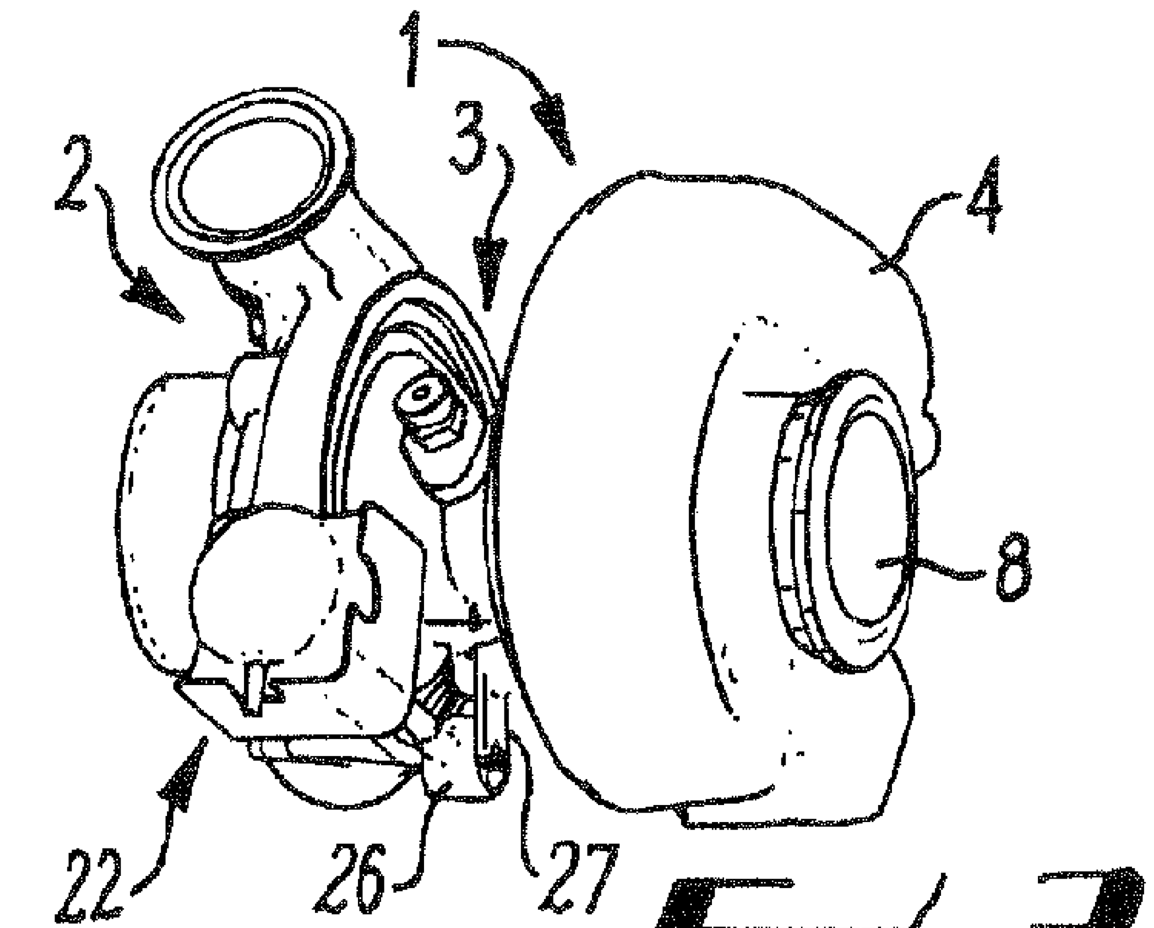

FIG. 3

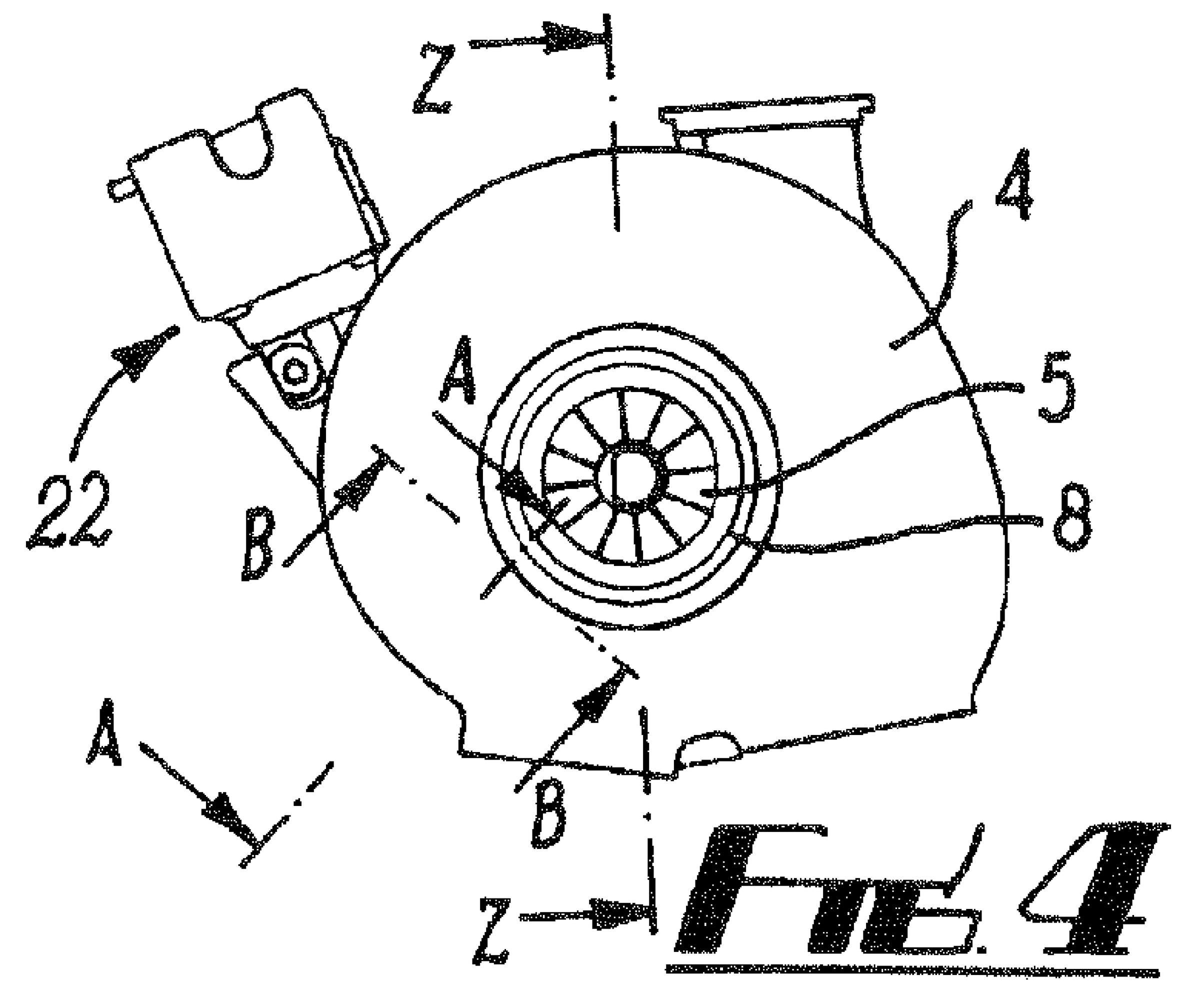

FIG. 4

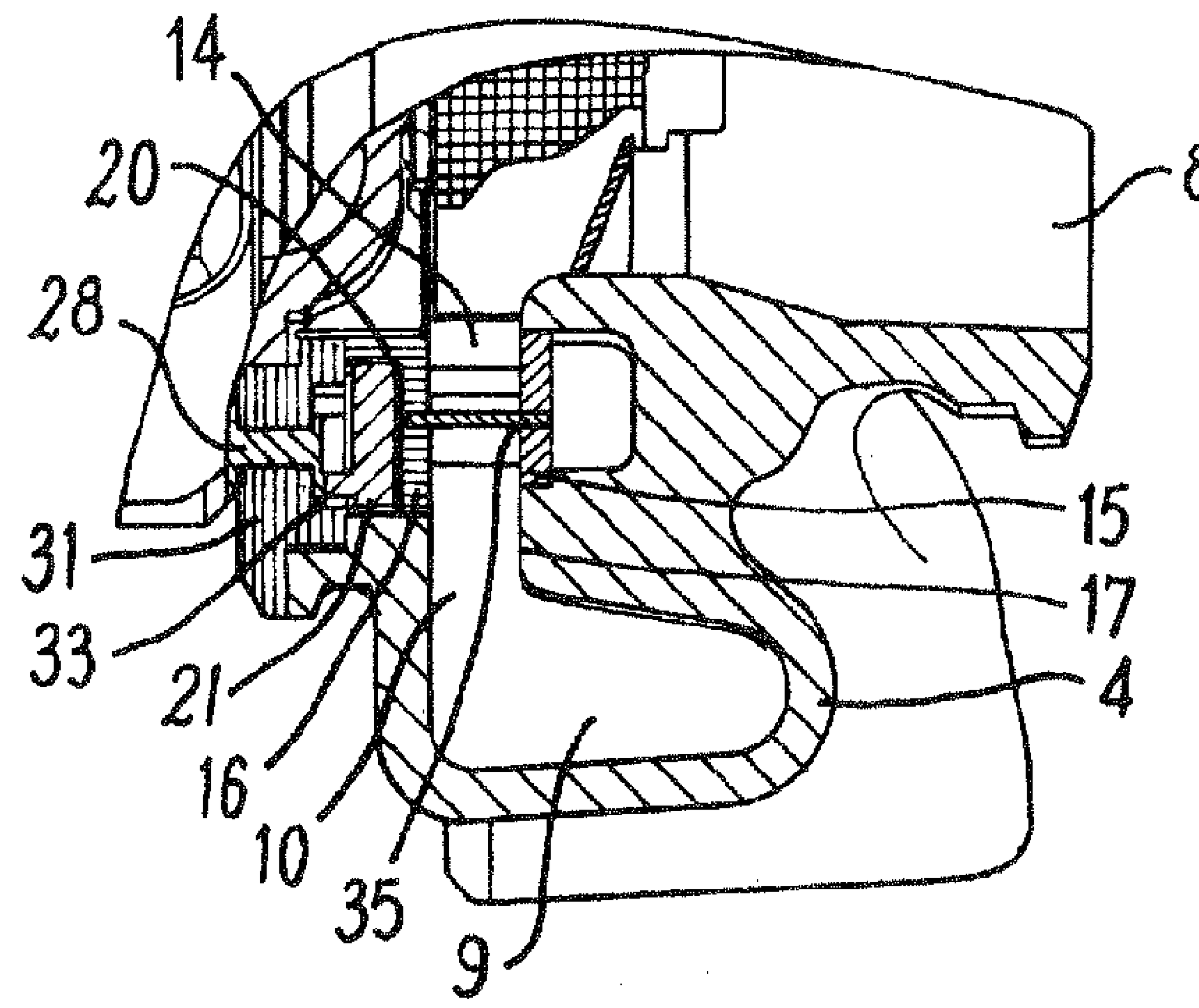

FIG. 5

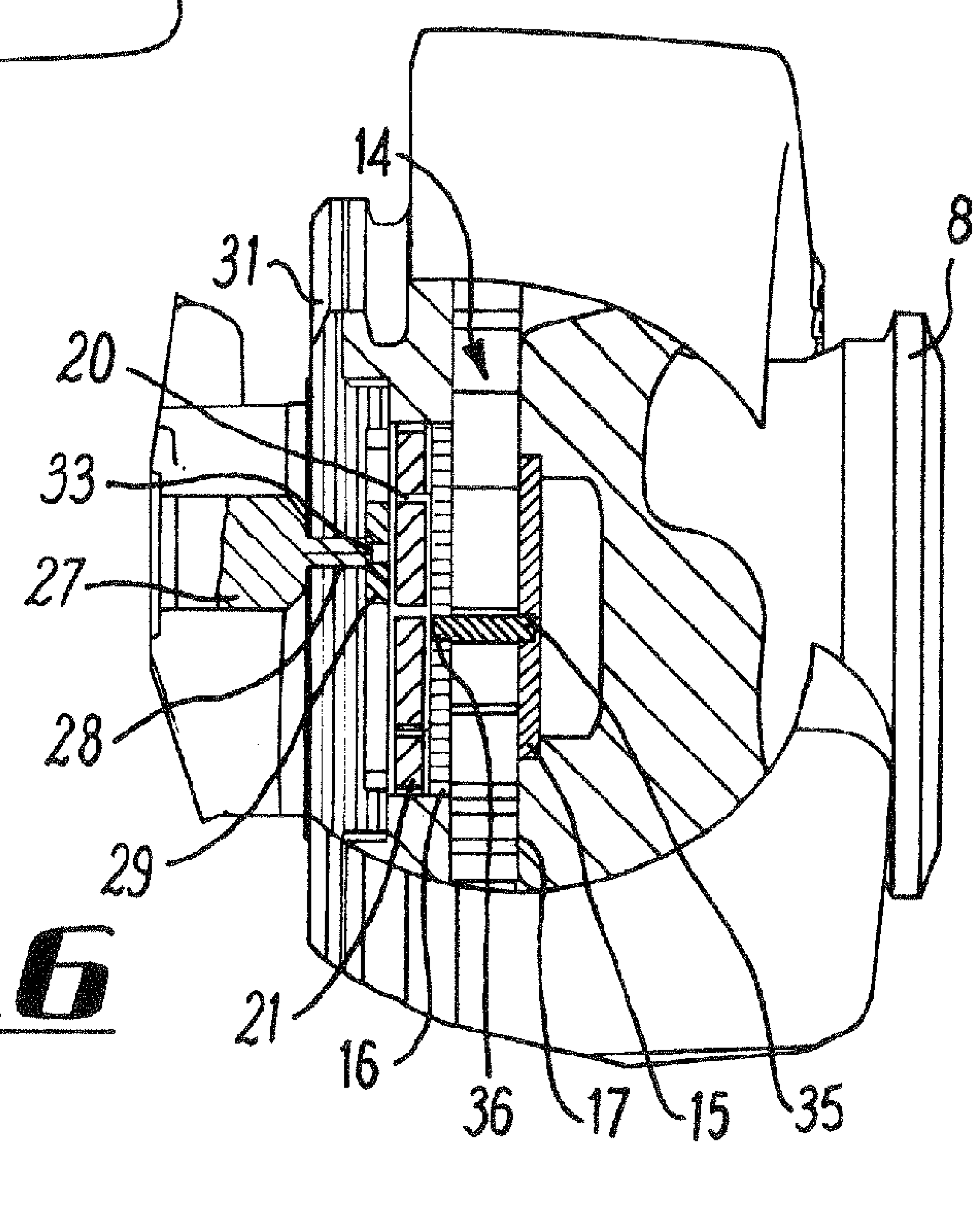

FIG. 6

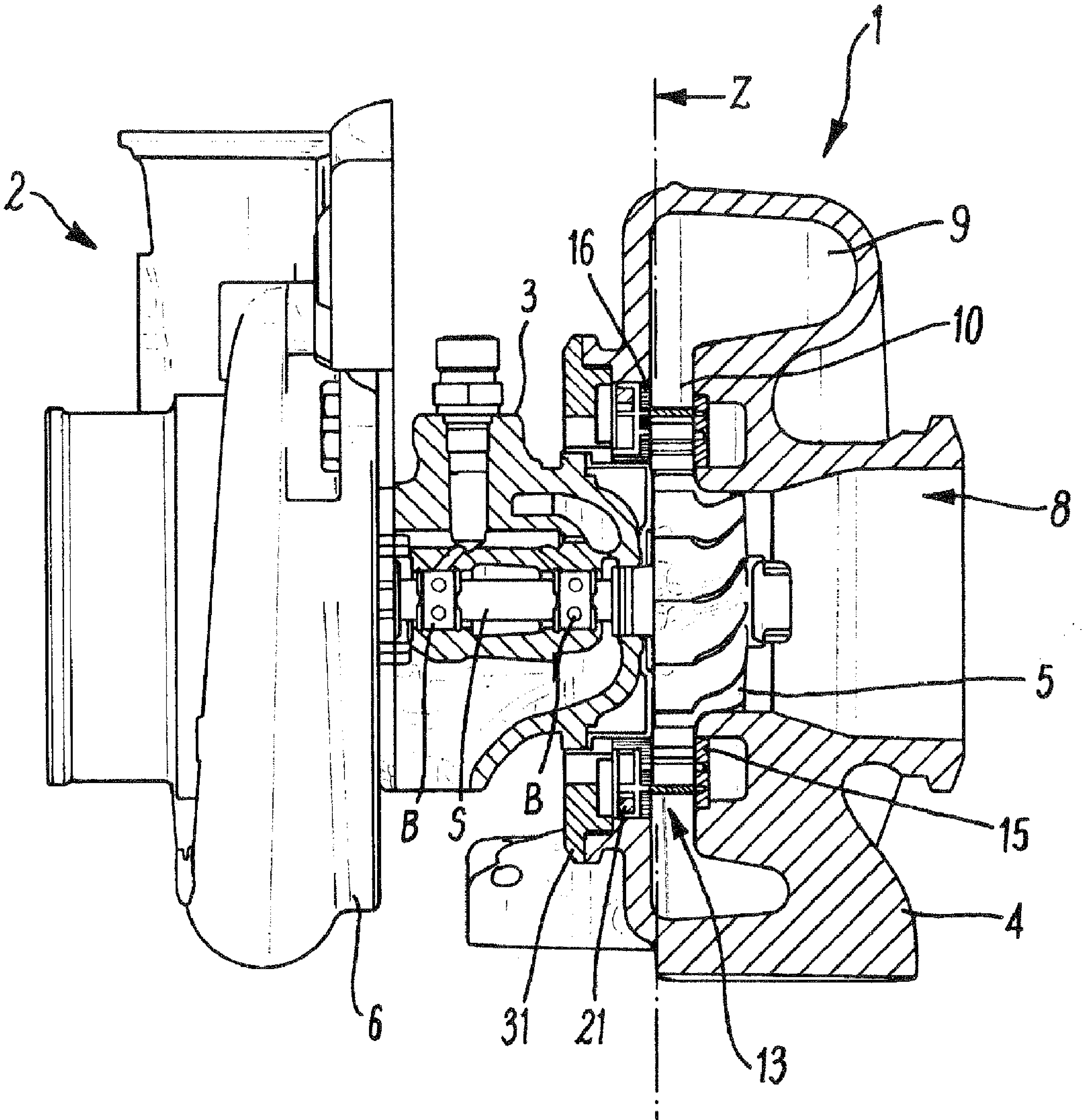

FIG. 7

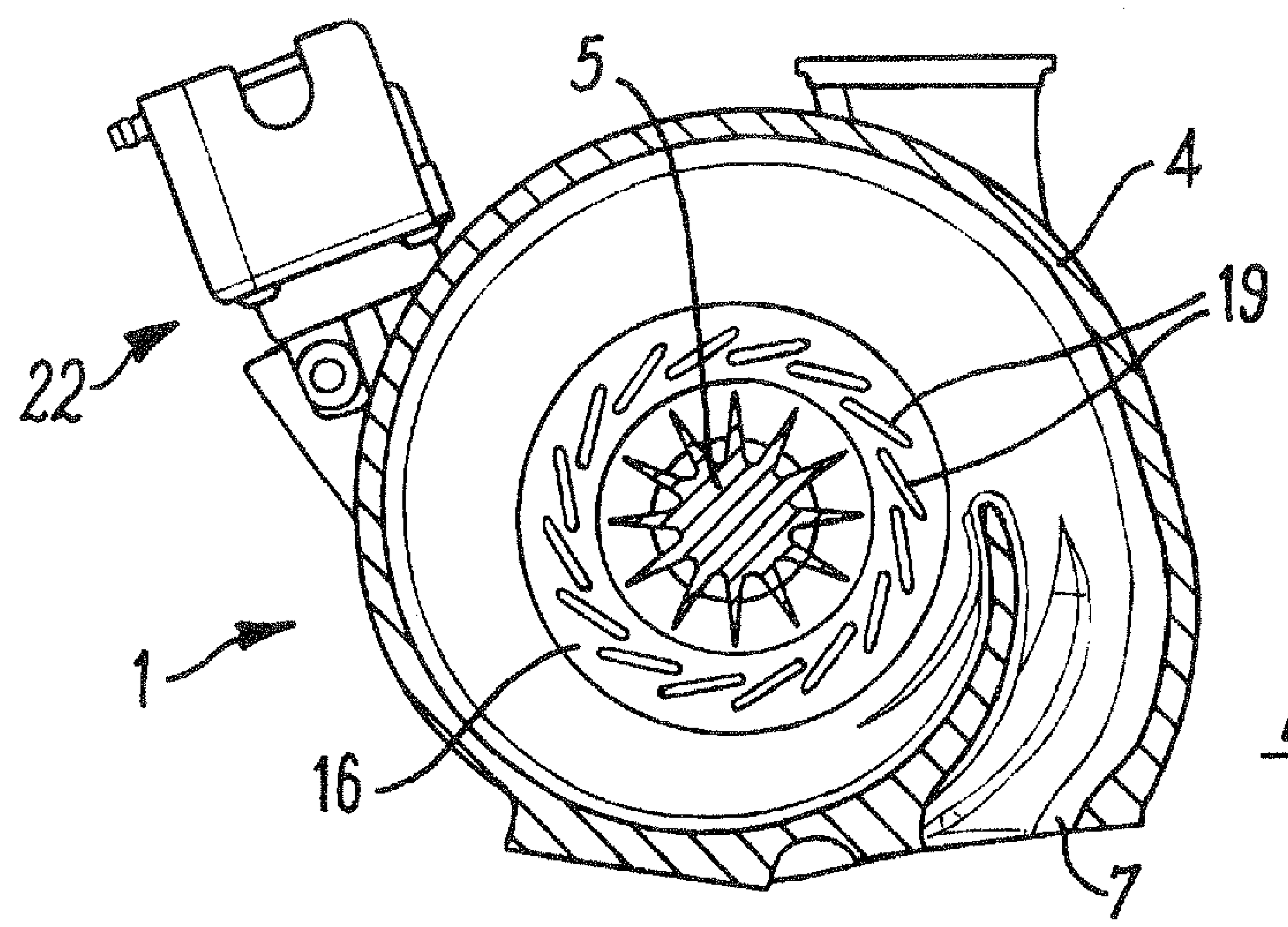

FIG. 8

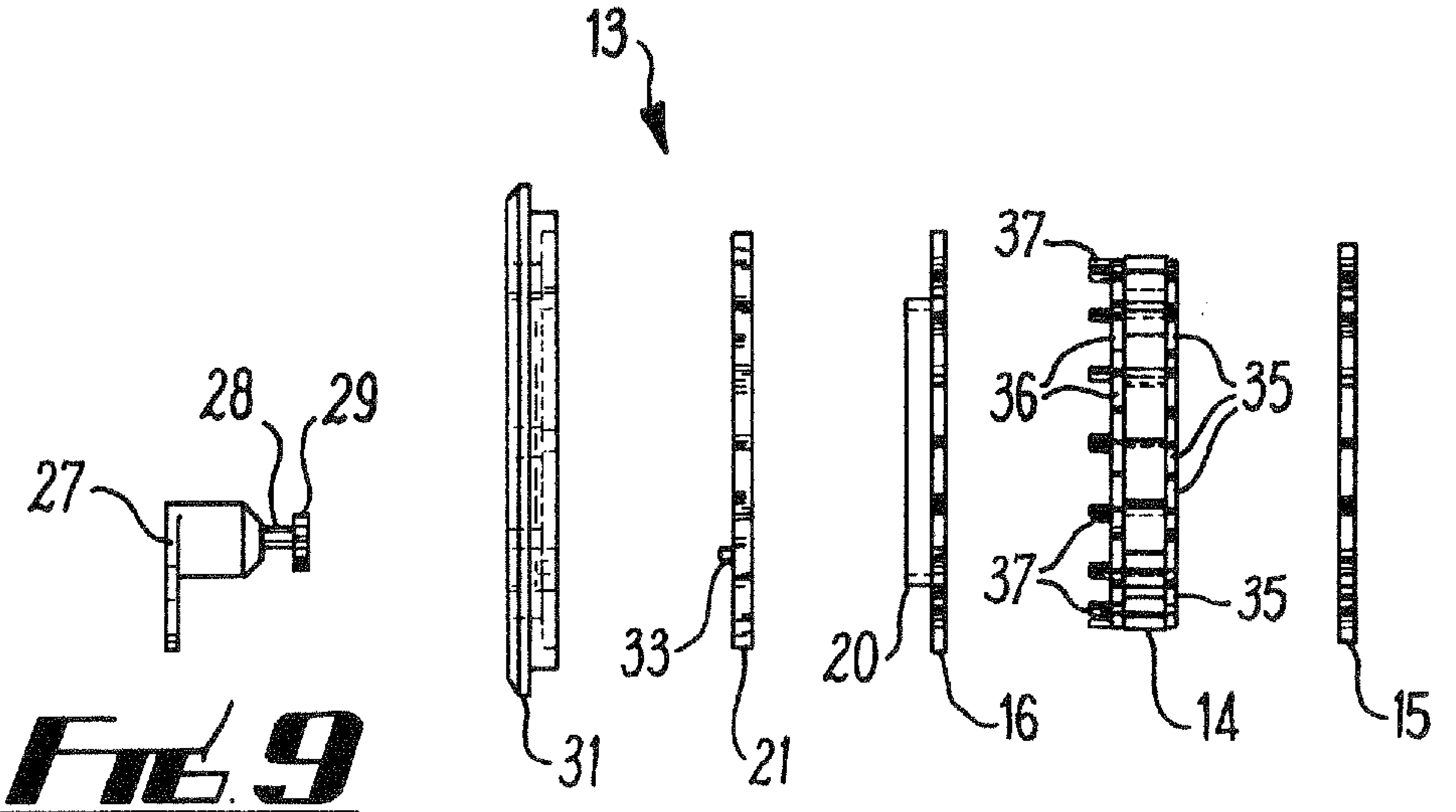

FIG. 9

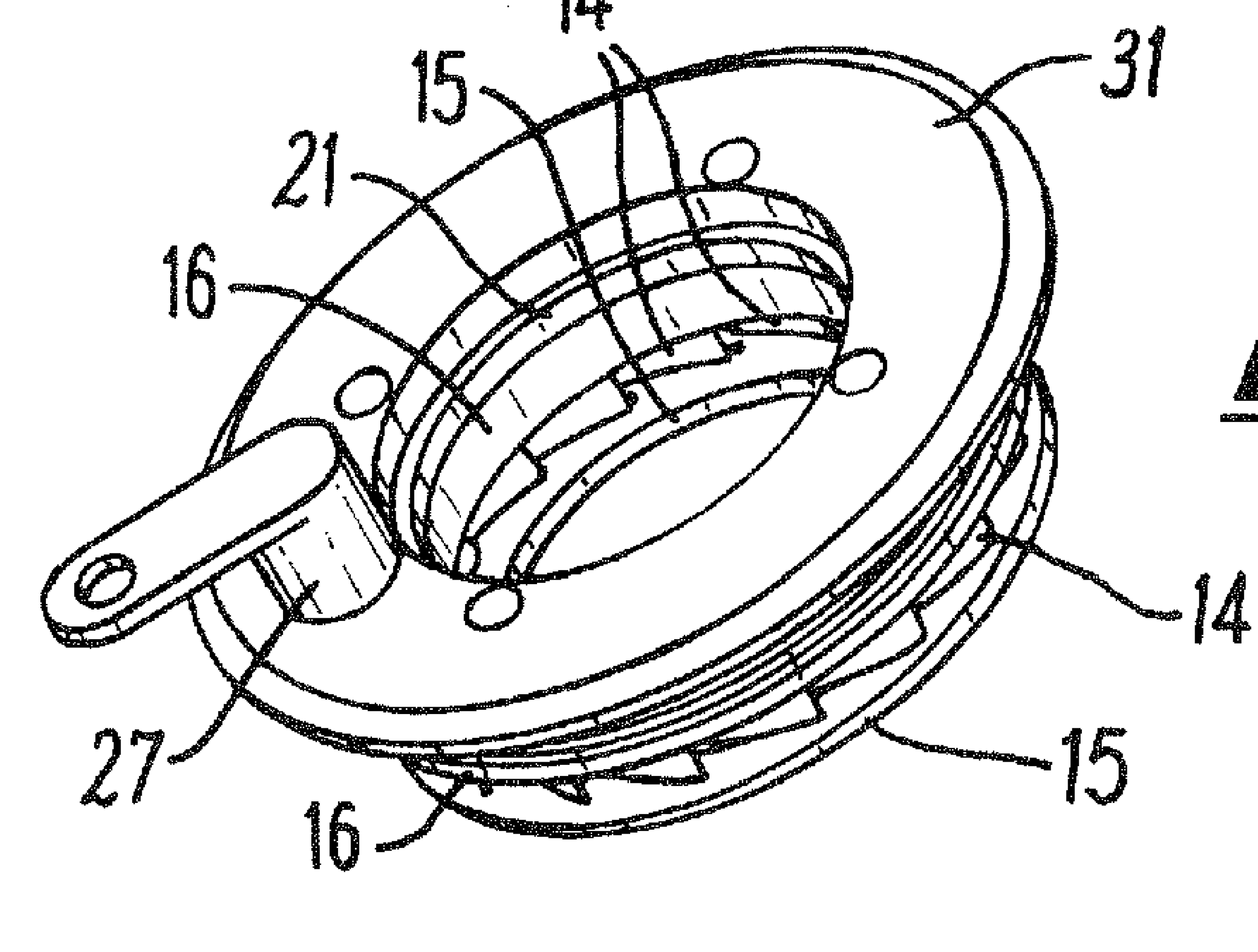

FIG. 10

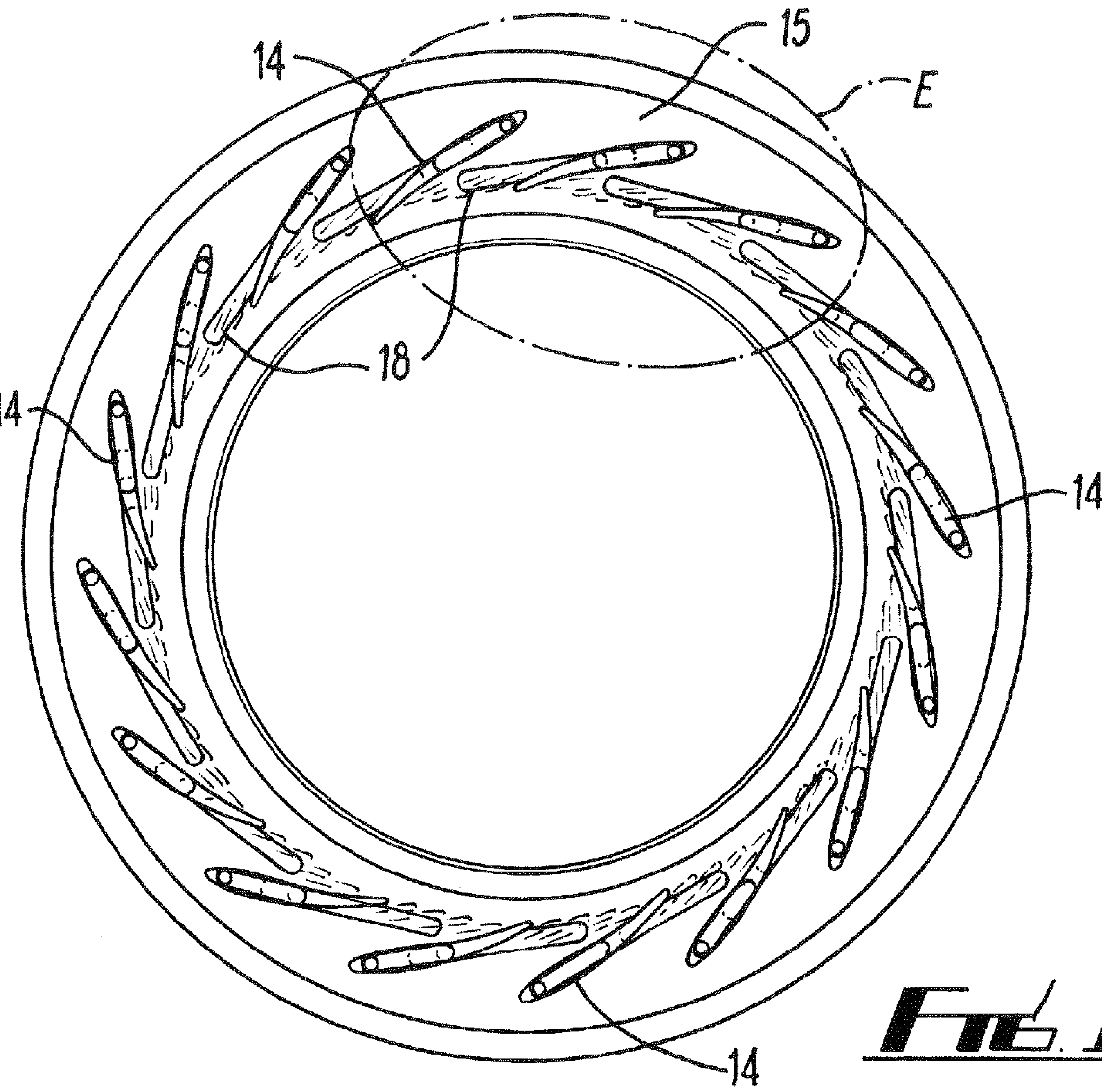

FIG. 11

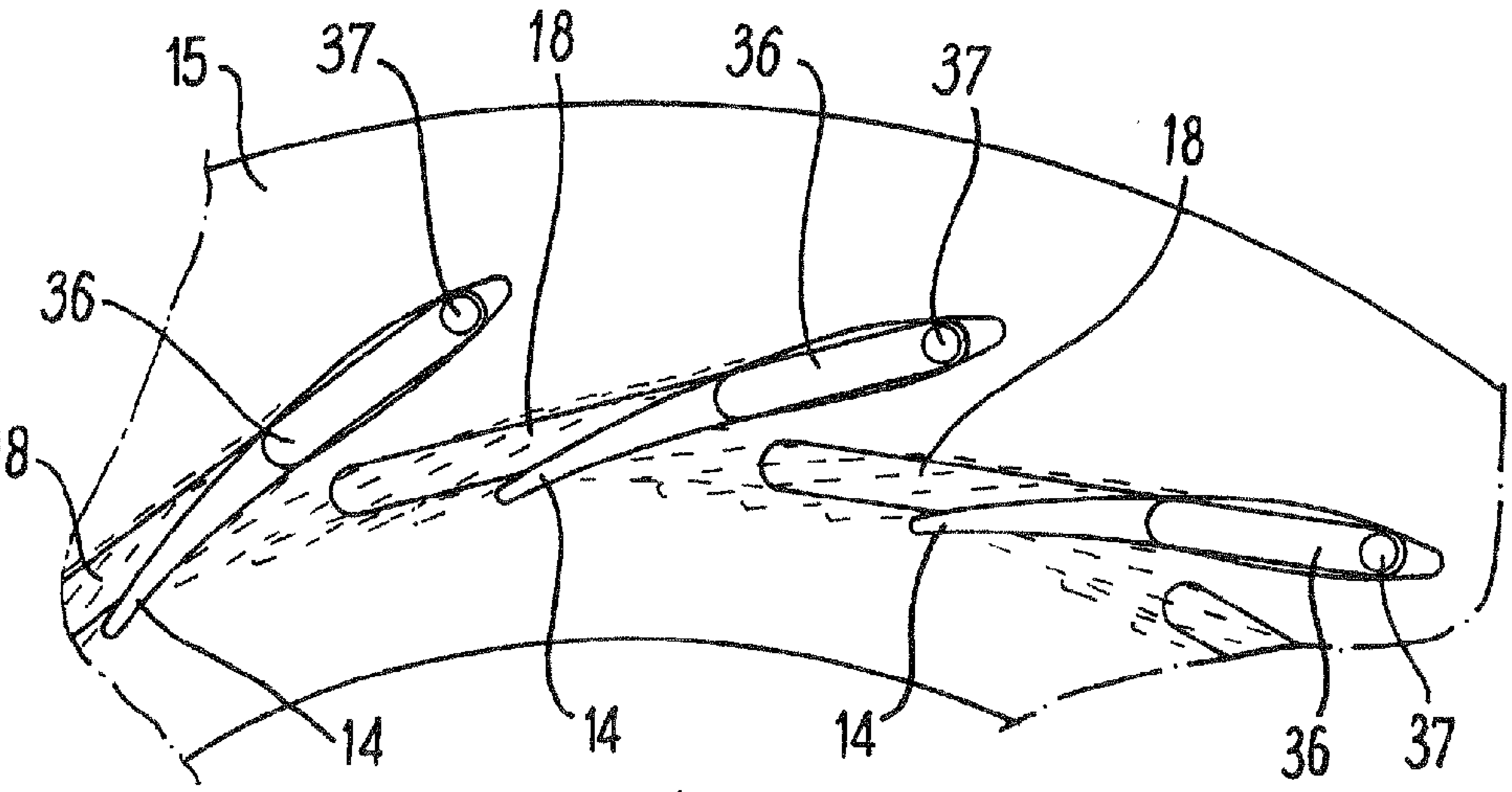

FIG. 11a

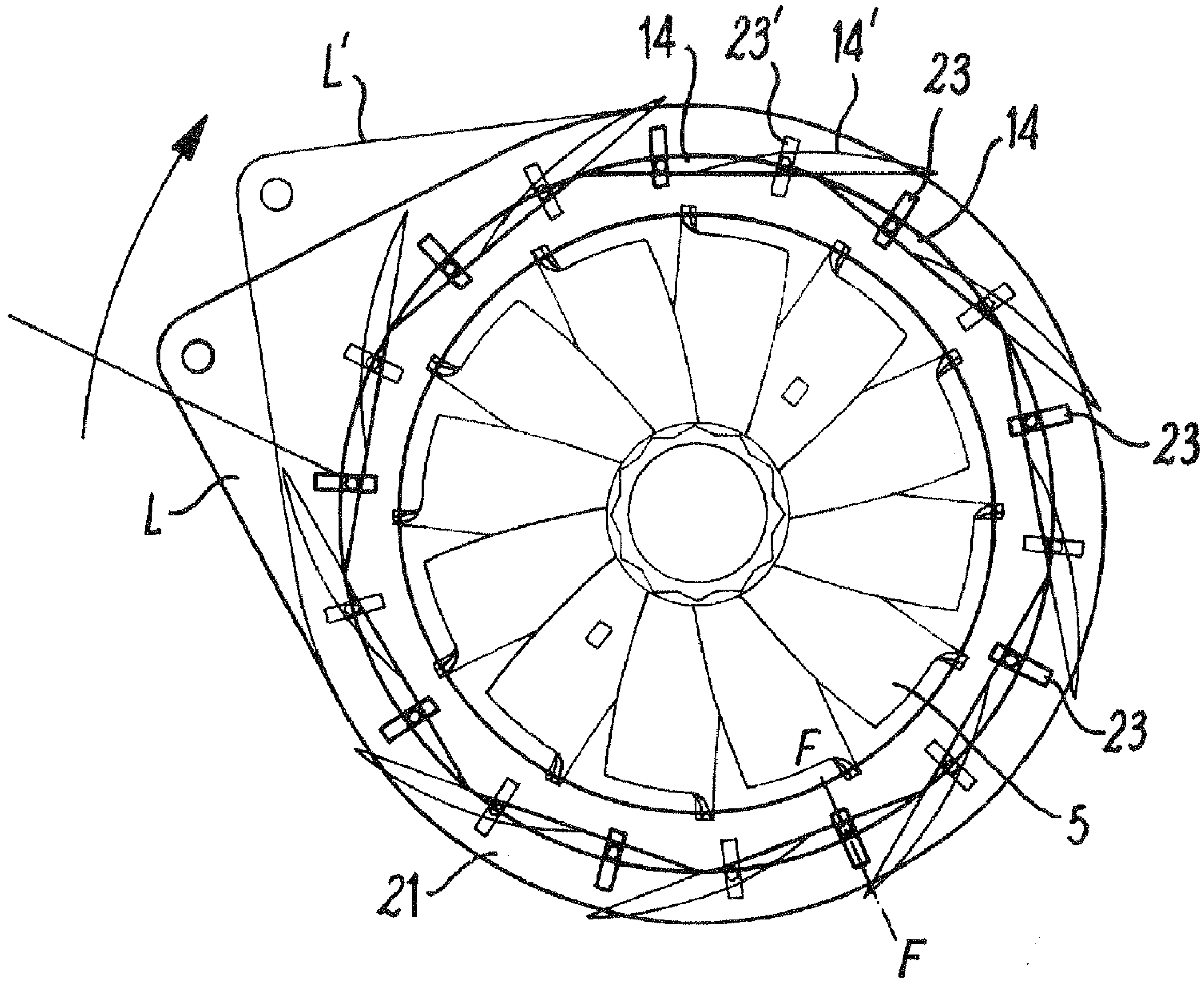

FIG. 12

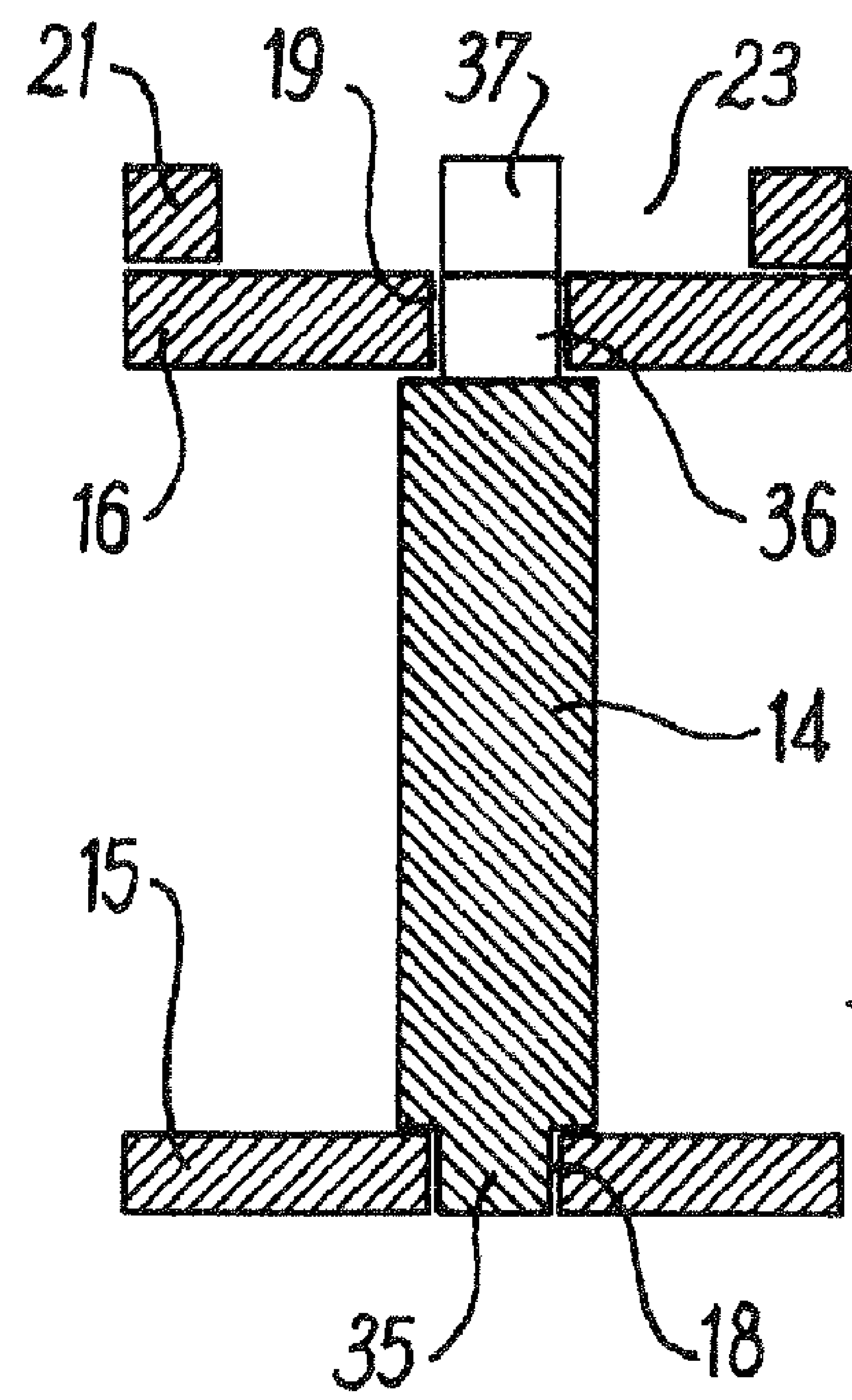

FIG. 12a

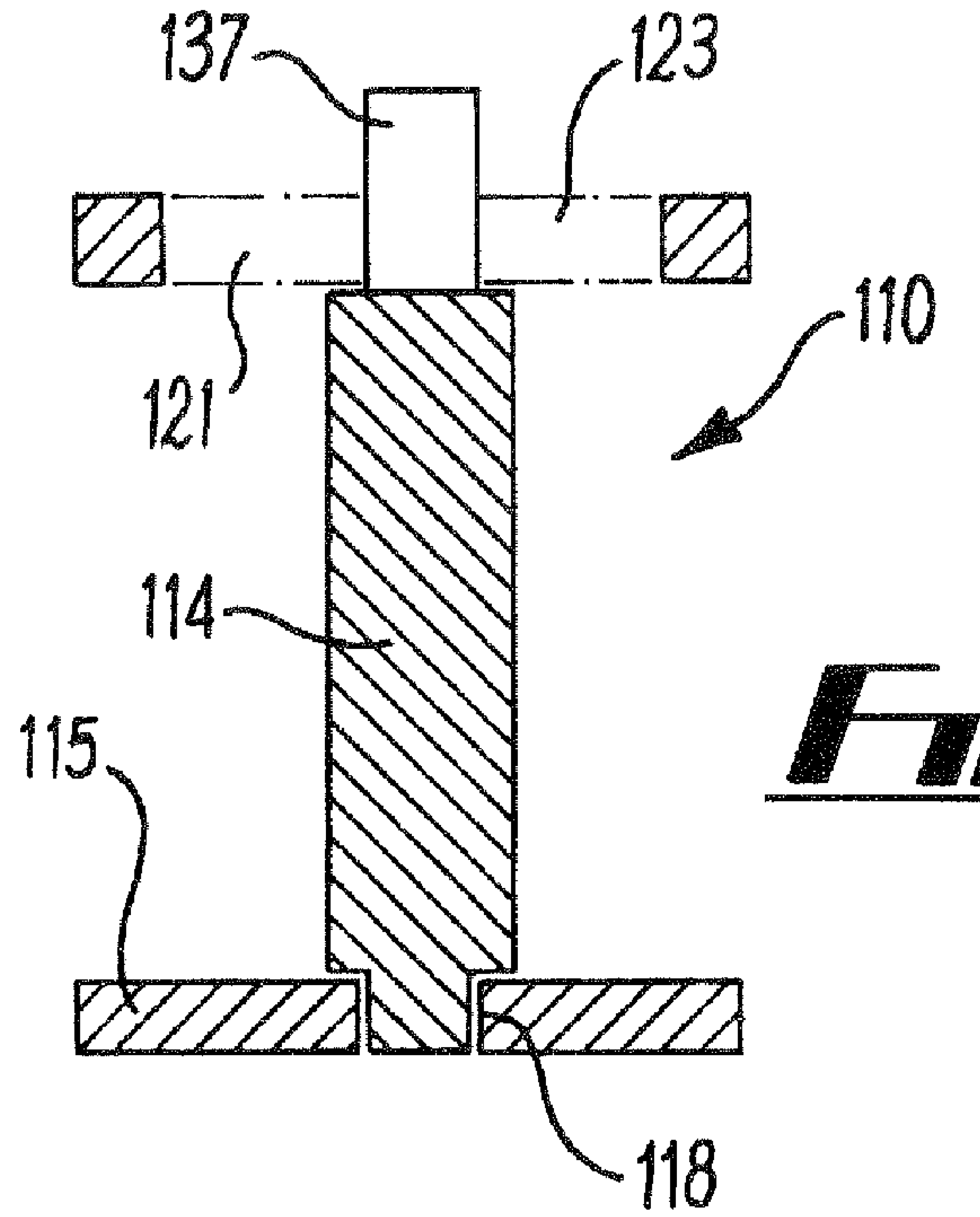

FIG. 13

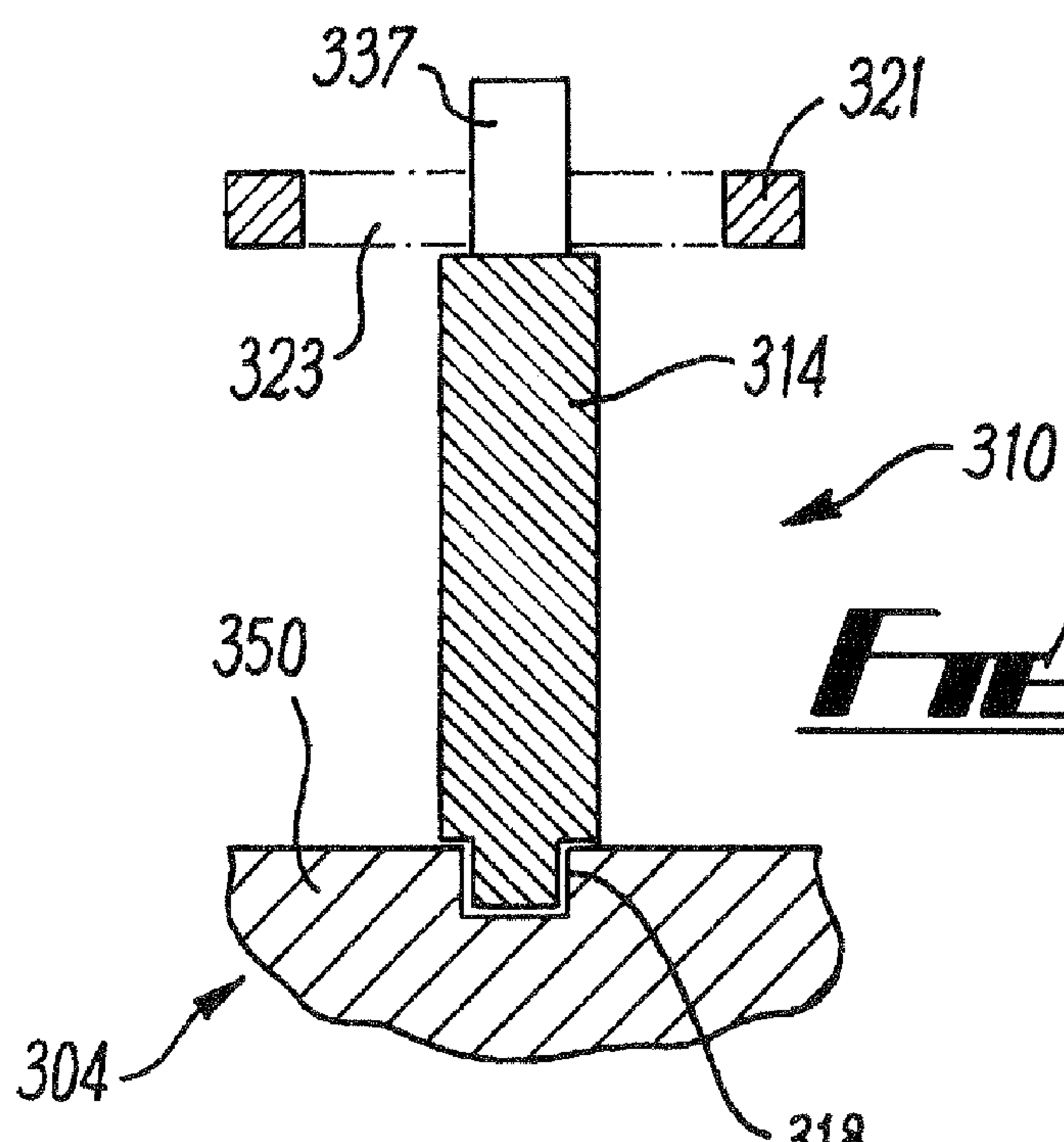

FIG. 15

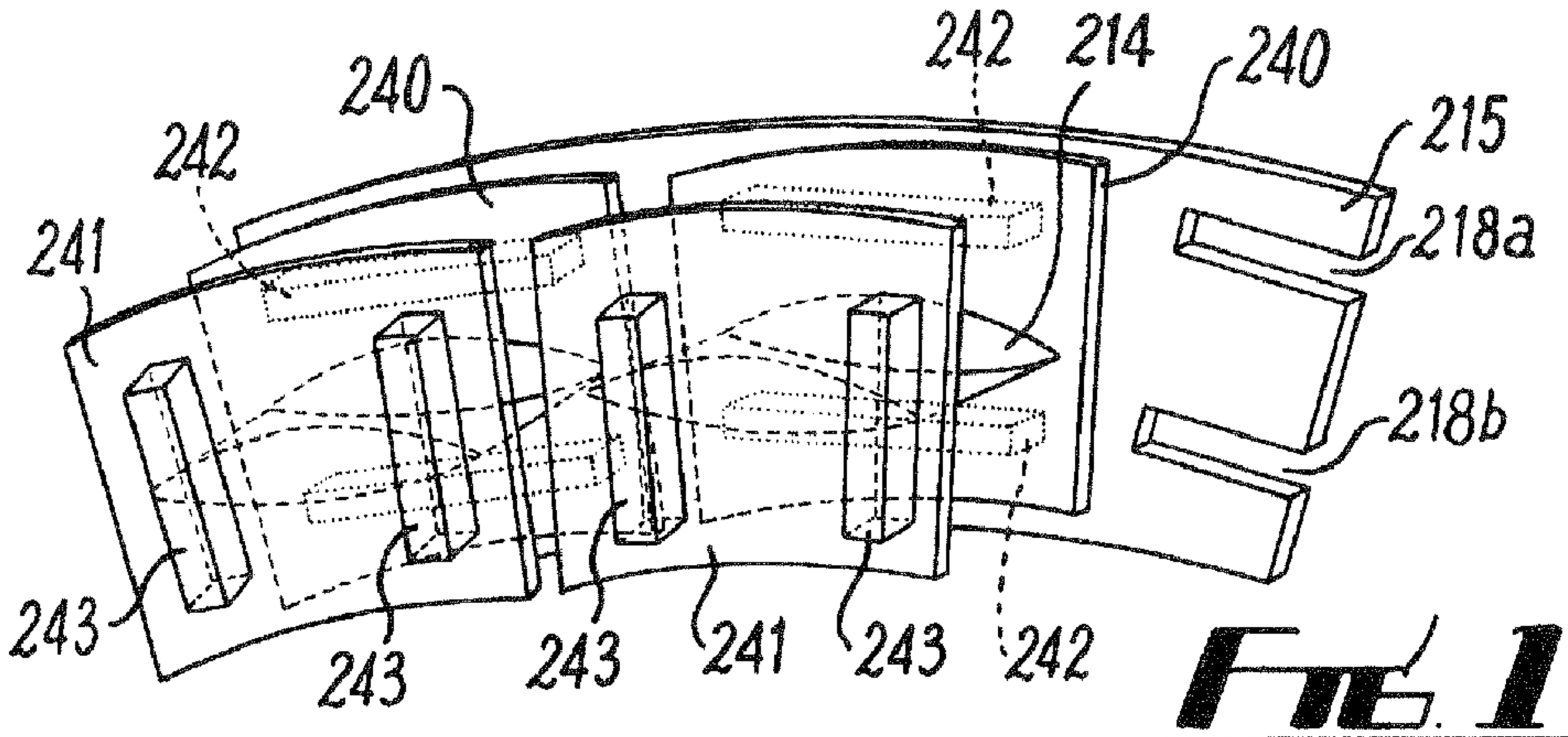

FIG. 14

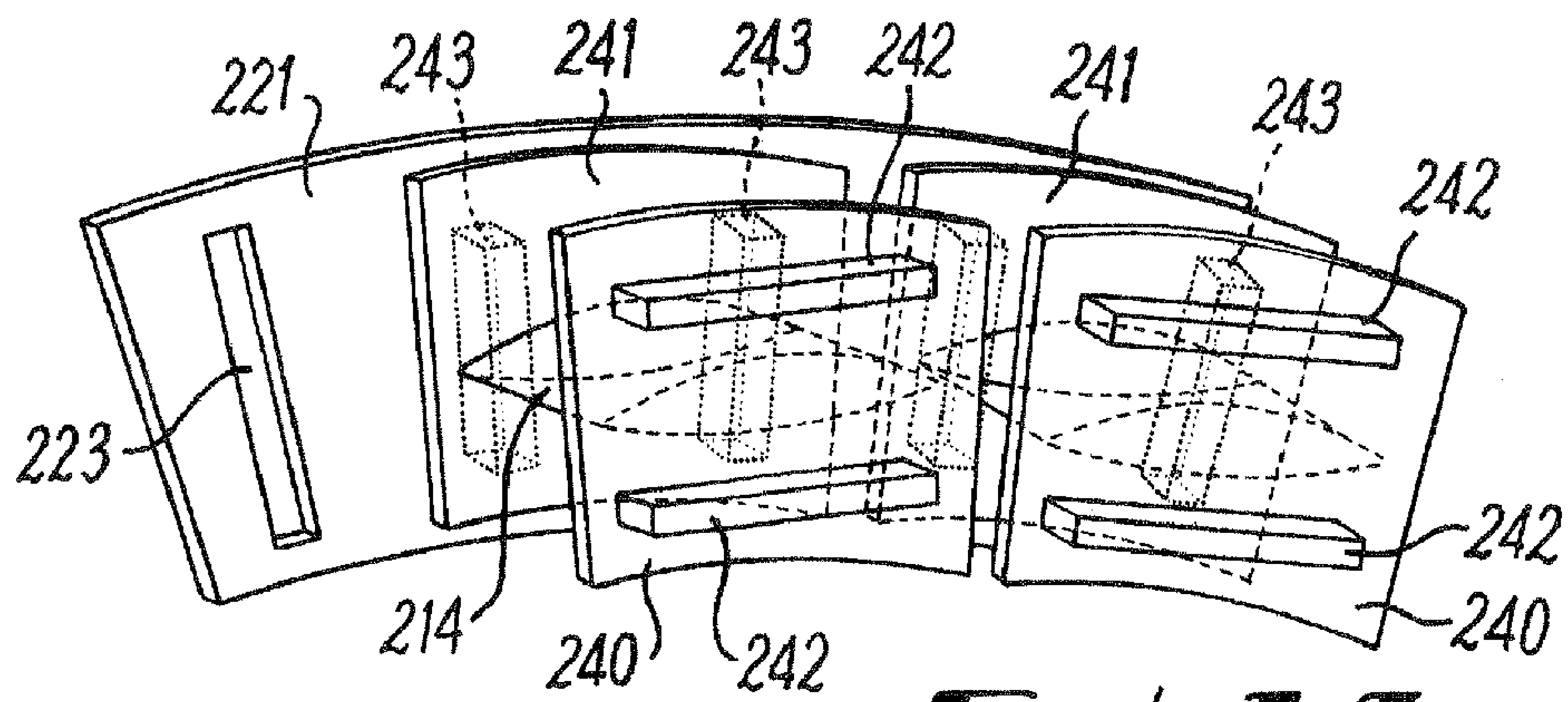

FIG. 14a

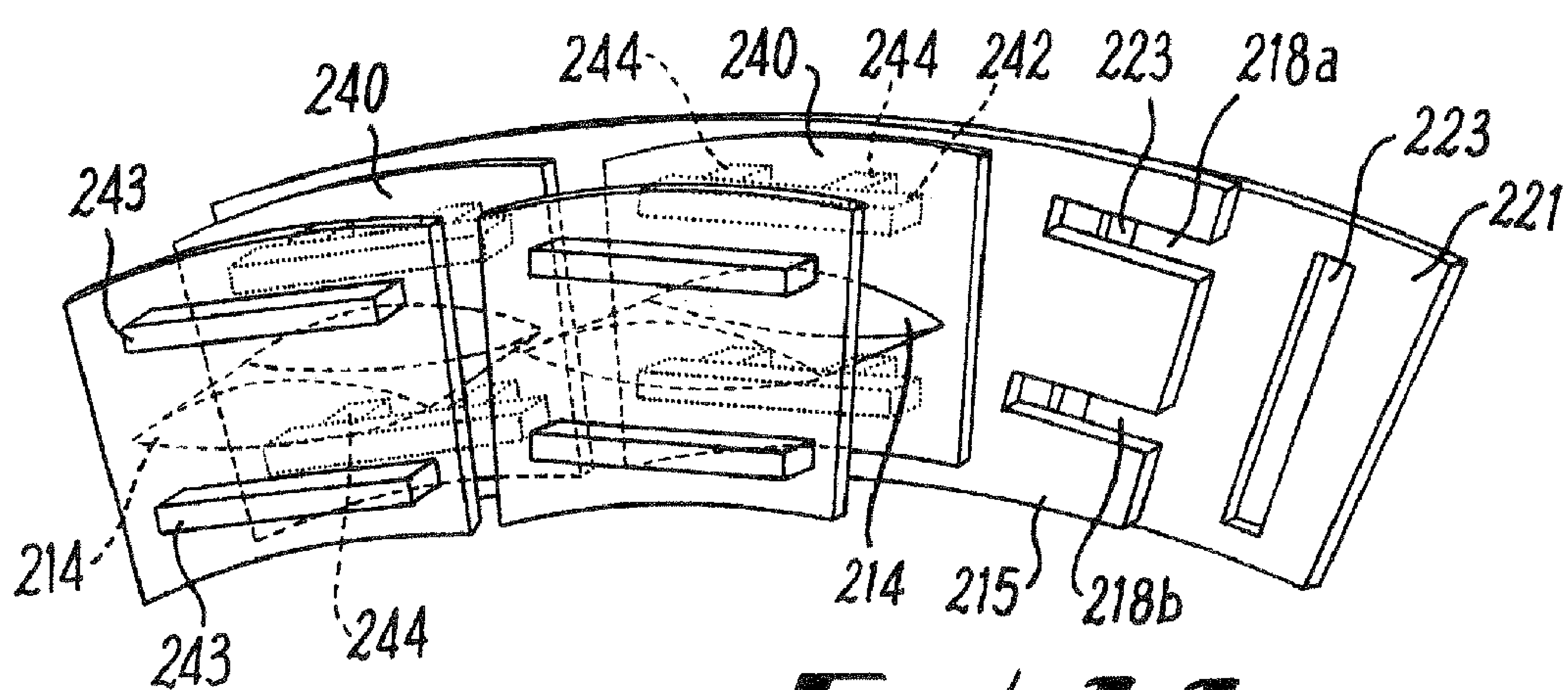

FIG. 14b

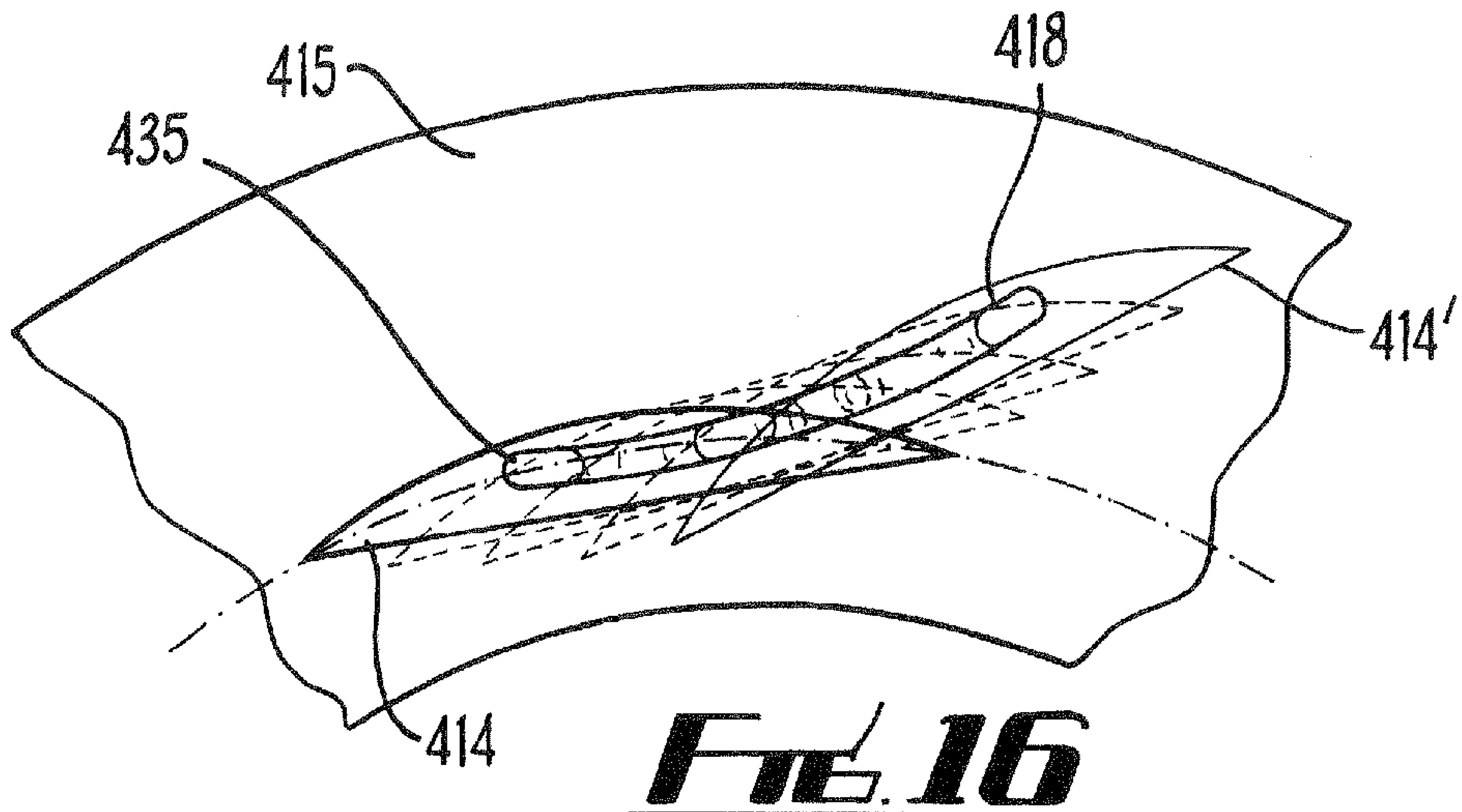

FIG. 16

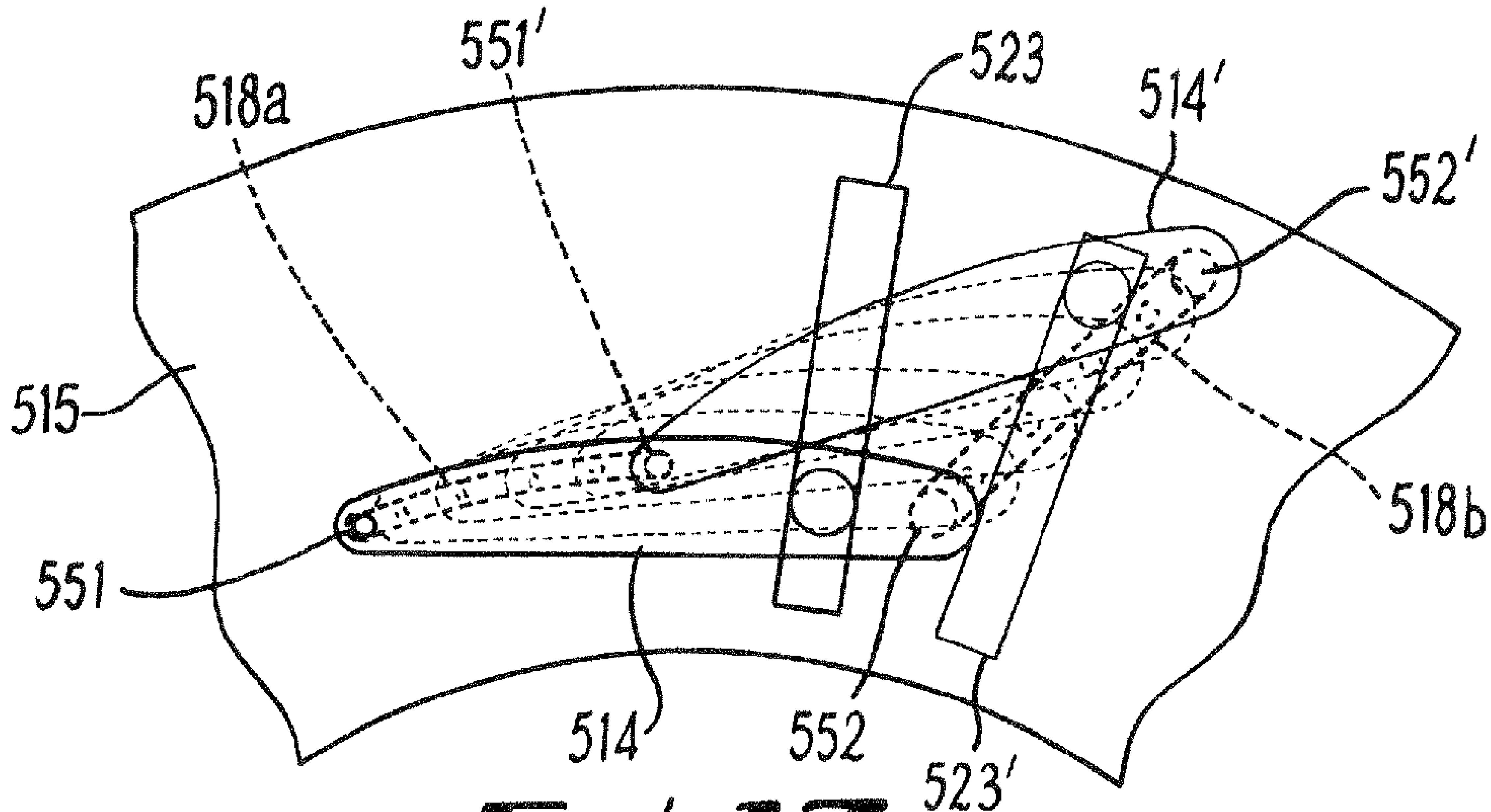

FIG. 17

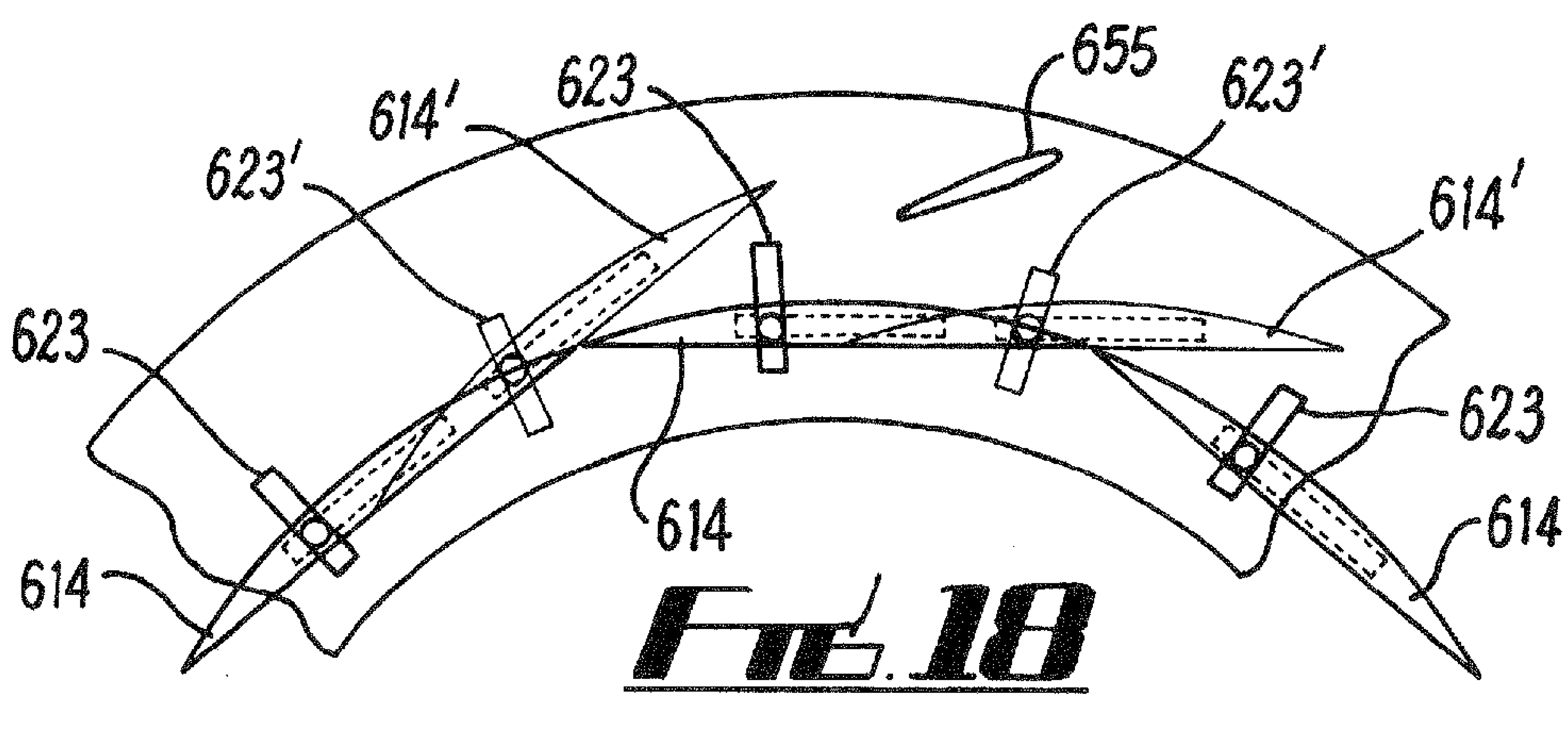

FIG. 18

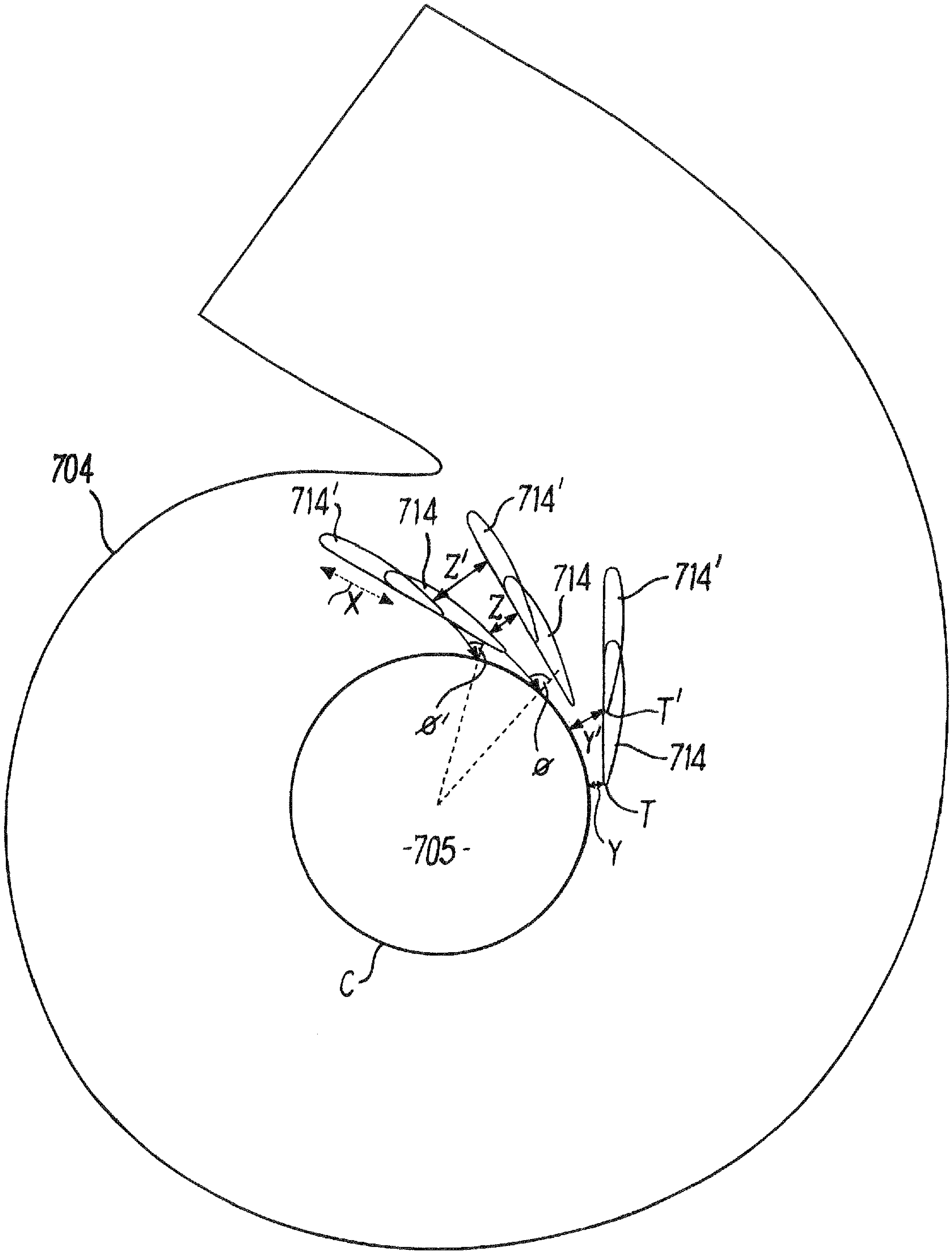

FIG. 19

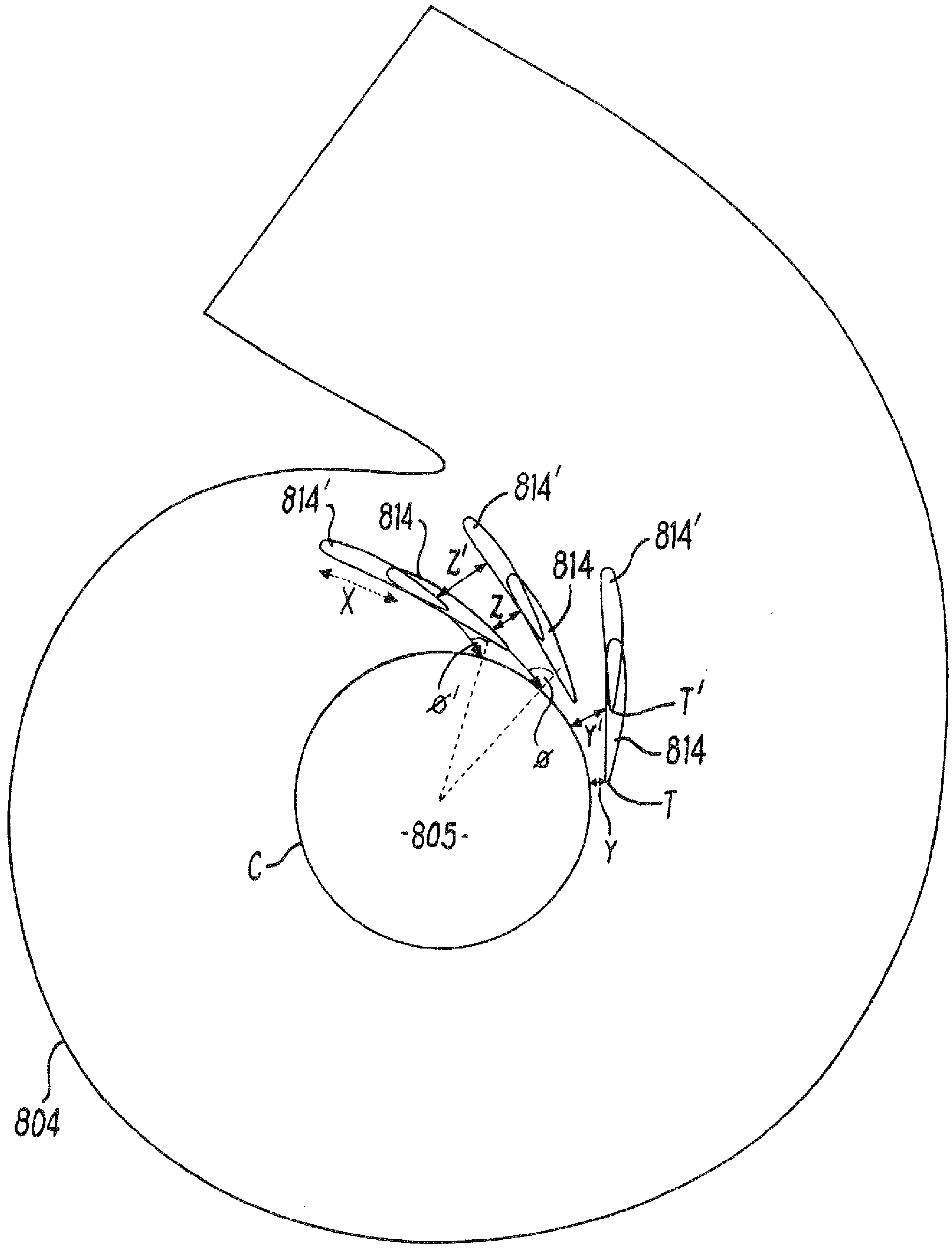

FIG. 20

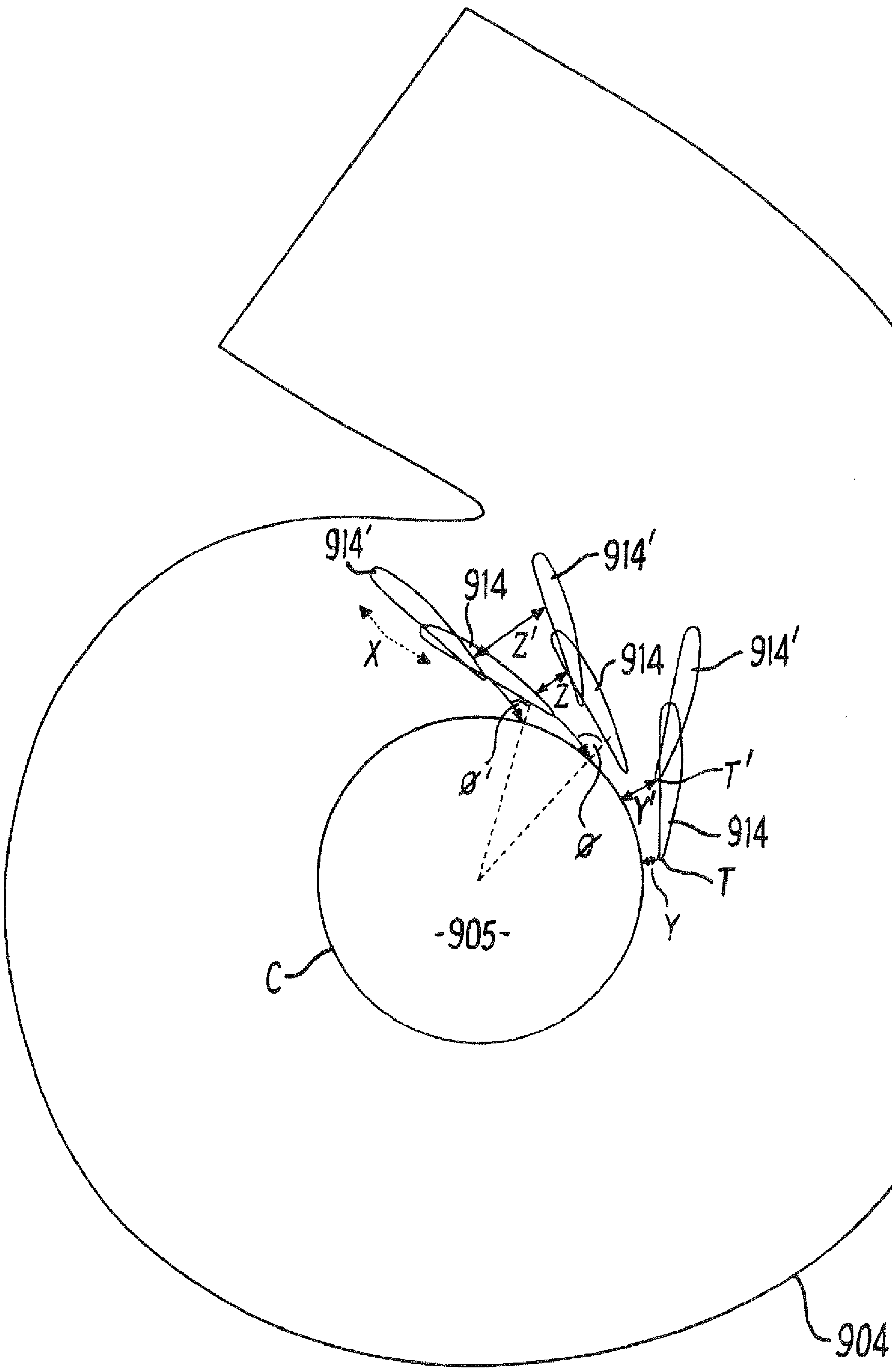

FIG. 21

VARIABLE GEOMETRY TURBINE

[0001] The present invention relates to a variable geometry turbine, a turbocharger incorporating such a variable geometry turbine for use with an internal combustion engine, and a variable geometry mechanism for varying the gas flow through such a turbine.

[0002] Turbochargers are well known devices for supplying air to the intake of an internal combustion engine at pressures above atmospheric pressure (boost pressures). A conventional turbocharger essentially comprises an exhaust gas driven turbine wheel mounted on a rotatable shaft within a turbine housing connected downstream of an engine outlet manifold. Rotation of the turbine wheel rotates a compressor wheel mounted on the other end of the shaft within a compressor housing. The compressor wheel delivers compressed air to the engine intake manifold. The turbocharger shaft is conventionally supported by journal and thrust bearings, including appropriate lubricating systems, located within a central bearing housing connected between the turbine and compressor wheel housings.

[0003] The turbine stage of a conventional turbocharger comprises: a turbine housing defining a turbine chamber within which the turbine wheel is mounted; an annular inlet passageway defined in the housing between facing radially extending walls arranged around the turbine chamber; an inlet arranged around the inlet passageway; and an outlet passageway extending from the turbine chamber. The passageways and chamber communicate such that pressurised exhaust gas admitted to the inlet flows through the inlet passageway to the outlet passageway via the turbine chamber and rotates the turbine wheel. It is known to improve turbine performance by providing vanes, referred to as nozzle vanes, in the inlet passageway so as to deflect gas flowing through the inlet passageway towards the direction of rotation of the turbine wheel. Turbines of this kind may be of a fixed or variable geometry type. Variable geometry turbines differ from fixed geometry turbines in that the size of the inlet passageway can be varied to optimise gas flow velocities over a range of mass flow rates so that the power output of the turbine can be varied in line with varying engine demands.

[0004] Nozzle vane arrangements in variable geometry turbochargers can take different forms. In one type, known as a sliding "nozzle ring", the vanes are fixed to an axially movable wall that slides across the inlet passageway. The axially movable wall moves towards a facing shroud plate in order to close down the inlet passageway and in so doing the vanes pass through apertures in the shroud plate. In another type the nozzle vanes are of the "swing vane" type. This comprises an array of movable vanes that is concentrically disposed around the turbine wheel with each vane pivotally supported on an annular vane carrier in the turbine inlet passageway. The vanes are each pivotable about a respective axle extending across the inlet parallel to the turbine axis and projecting through a wall of the inlet. The axle supports a crank or lever outside the inlet and a vane actuating mechanism connected to each crank is displaceable in a manner that causes each of the vanes to move in unison, such a movement enabling the cross-sectional area available for the incoming gas, and also the angle of approach of the gas to the turbine wheel, to be controlled. For instance, orientating the vanes so that their chords are generally radial to the wheel increases the spacing between adjacent vanes, thus increasing the cross-sectional flow area of the passageway—referred to as the turbine "throat". On the other hand, pivoting the vanes so that their chords extend generally circumferentially to the wheel reduces the space between adjacent vanes thus reducing the turbine throat. The product of the throat dimension and the fixed axial length of the vanes extending across the inlet passageway, determines the flow area for any given vane angle.

[0005] In conventional swing vane mechanisms of the kind described above the change in angle of the vanes affects blade vibration as the distance between the trailing edges of the vanes and the turbine wheel changes as the vanes pivot. As the inlet passageway of the turbine is opened by pivoting the vanes the trailing edges of the vanes move closer to the periphery of the turbine wheel with the result that vibration occurs in the vanes. This results in metal fatigue over prolonged periods of use.

[0006] It is one object of the present invention to provide for an improved variable geometry turbine.

[0007] According to a first aspect of the present invention there is provided a variable geometry turbine comprising: a housing defining a chamber within which a turbine wheel is mounted for rotation about a turbine axis such that its outer periphery substantially describes a swept circumference; the chamber having a gas inlet disposed radially outboard of an outer periphery of said turbine wheel; a plurality of vanes arranged around the turbine axis, each vane having a vane height extending between a first end and a second end in a direction across the inlet in a substantially axial direction and each vane being movable so as to adjust the effective cross-section area of the inlet between a first position in which the area of the inlet is a minimum and a second position in which the area of the inlet is a maximum; at least one guide member having a plurality of first guide tracks for engagement with the first ends of the vanes; a vane actuator for effecting translational movement of the plurality of vanes relative to the housing between the first and second positions, the vane actuator having a plurality of actuation tracks for engagement with the plurality of vanes, the vane actuator being rotatably disposed in the housing such that rotation of the vane actuator induces sliding translation of each of the plurality of vanes relative to a respective first guide track in a first direction and sliding translation of each of the plurality of vanes relative to the respective actuation track in a second direction, the second direction being different to the first direction; wherein in the first position the vanes are disposed such that at a given turbine pressure ratio they direct the gas to the turbine wheel such that it has a first swirl angle at the swept circumference of the turbine wheel and in the second position the vanes are disposed such that at the same turbine press ratio they direct the gas to the turbine wheel such that it has a second swirl angle at the swept circumference, the first swirl angle being greater than the second swirl angle.

[0008] The swirl angle is defined by the angle of the gas incident on a radial plane that intersects the axis of the turbine wheel, as will be understood by those skilled in the art. The first swirl angle being greater than the second angle means that it is closer to a tangent to the circumference swept by the turbine wheel as it rotates.

[0009] The change in swirl angle means that trailing edges of the vanes do not move significantly away from the turbine wheel in the radial direction as the vanes move from the second to the first position and may in some embodiments move closer.

[0010] The guide and/or actuation tracks may be in the form of slots that receive a projection on the vanes or alternatively may be in the form of projections that engage with corresponding slots in the vanes. The slots may be through slots that penetrate through the guide member or blind slots that do not penetrate through. The guide member may be a ring that is fixed (releasably or otherwise) to the housing or may be an integral part of the housing.

[0011] The plurality of vanes may all move together in the same angular direction relative to the radial direction. It is to be understood that in one embodiment there may be one or more other vanes besides the plurality of vanes that are fixed or which do not move in the same manner. However, in another embodiment all of the vanes move in unison.

[0012] The first aspect of the invention provides for a variable geometry turbine in which the vanes translate in a sliding movement at both ends upon movement by the actuator. This allows for accurate control of the trailing edge position of the vanes relative to the periphery of the turbine wheel and accurate control of the size of the exposed inlet area. The variation of the inlet area may be independent of the change in vane angle. The change in swirl angle may assist in reducing turbine wheel blade vibration and resulting blade fatigue.

[0013] The first ends of the plurality of vanes may have at least one projection and the plurality of first guide tracks may be in the form of first guide slots, the at least one projection of each vane may be received in a respective first guide slot. The at least one projection may be in the form of an elongate tab that extends in the direction between leading and trailing edges of each vane.

[0014] The plurality of first guide slots may extend substantially in a direction that is substantially tangential to an imaginary circle about the turbine axis. Alternatively they may be inclined to the tangential direction by up to 40 degrees. The direction may have both tangential and radial components and the relationship between the two components may be linear such that the slot extends in a linear fashion. The tangential component may be dominant. Alternatively the relationship may be non-linear such that the slot extends in a curve.

[0015] The plurality of actuation tracks in the vane actuator may be in the form of slots. The actuation tracks may extend in a substantially radial direction or otherwise.

[0016] The guide member and the vane actuator may be spaced apart in the axial direction, the plurality of vanes being disposed between them. Alternatively they may be disposed at one end of the vanes, such as, the first end of the vanes.

[0017] The second ends of the vanes may each have at least one projection and the actuation tracks may be in the form of slots, the at least one projection of the second ends being received in a respective slot in the vane actuator. The slots may be through slots in that they penetrate through the vane actuator. The at least one projection may comprise a pin that extends into the respective slot.

[0018] The guide member may be defined by a wall of the turbine housing that is adjacent to the inlet.

[0019] The first guide member may be substantially annular.

[0020] There may be provided a first guide member that may have the plurality of first guide tracks and a second guide member that may be spaced apart from the first guide member in an axial direction and may have a plurality of second guide tracks for engagement with the second end of the plurality of vanes. The second guide tracks may be slots which penetrate the second guide member. Each of the second ends of the vanes may have a projection for receipt in the guide tracks. The pins may extend from the projections and may be integrally formed therewith. The projection may be in the form of elongate tabs extending in a direction between leading and trailing edges of the vanes. The pins may translate in the respective actuation tracks during movement of the vanes.

[0021] The first and second guide tracks may be substantially identical.

[0022] The plurality of vanes may have a flange at one or both of the first and second ends. The vane projections may extend from the flanges at each end.

[0023] The plurality of vanes may be disposed in a generally circumferential array concentric with the turbine wheel.

[0024] The plurality of vanes may each have a pair of projections at a first end for receipt in the first guide tracks. There may be a pair of first guide tracks for each of the plurality of vanes and the pair of first guide tracks may have substantially identical profiles or they may have different profiles.

[0025] The vane actuator may be a unison ring that may be substantially annular. The unison ring may have a formation that is couplable to an actuator drive member. The actuator drive member may be coupled to the unison ring by means of a link that engages with a formation defined on the unison ring. The formation may be in the form of a pin. The drive member may be a reciprocal piston rod that is coupled to the formation. It may be coupled to the formation by means of a cranked arm. The piston rod may have a boss in which one end of the cranked arm is pivotally connected. The other end of the cranked arm may have a spindle that is coupled to the formation. The spindle may support a disc for coupling to the formation. The disc may have a slot for engagement with the pin such that the pin may slide relative to the slot during driving of the vane actuator.

[0026] The unison ring may be supported on a flange of the second guide member.

[0027] The vanes may define trailing edges proximate the turbine wheel. In the first position the trailing edges of the vanes may be at a first distance from the turbine wheel swept circumference, in the second position the trailing edges of the vanes may be at a second distance from the swept circumference, the first distance being shorter than the second distance. This helps to reduce turbine wheel blade vibration and resulting blade fatigue.

[0028] According to a second aspect of the present invention there is provided a turbocharger comprising a compressor driven by an exhaust gas variable geometry turbine as defined above.

[0029] According to a third aspect of the present invention there is provided a variable geometry mechanism for varying the gas flow through a turbine as defined above.

[0030] According to a fourth aspect of the present invention there is provided an internal combustion engine fitted with a turbocharger as defined above such that compressed air is deliverable from the compressor to an inlet manifold of the engine and exhaust gas from an exhaust manifold is delivered to the inlet of the variable geometry turbine of the turbocharger.

[0031] Specific embodiments of the present invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

[0032] FIG. 1 is an exploded front perspective view from one side of a turbocharger incorporating a variable geometry turbine in accordance with an aspect of the present invention;

[0033] FIG. **2** is an exploded rear perspective view from the same side of the turbocharger of FIG. **1**;

[0034] FIG. **3** is a perspective view from the front and side of the turbocharger of FIG. **1** shown in the assembled condition;

[0035] FIG. **4** is a front view of the turbocharger of FIG. **3**;

[0036] FIG. **5** is a part-sectioned view along line A-A of FIG. **4**;

[0037] FIG. **6** is a part-sectioned view along line B-B of FIG. **4**;

[0038] FIG. **7** is a part-sectioned view along line Z-Z of FIG. **4**;

[0039] FIG. **8** is a sectioned view along line C-C of FIG. **7**;

[0040] FIG. **9** is an exploded side view of a variable geometry mechanism of the turbocharger of FIGS. **1** to **8**;

[0041] FIG. **10** is a perspective view of the variable geometry mechanism of FIG. **9** shown in assembled form;

[0042] FIG. **11** illustrates the movement of vanes of the variable geometry mechanism between open and closed positions;

[0043] FIG. **11***a* is an enlarged view of the portion of FIG. **11** ringed and labelled E;

[0044] FIG. **12** is a schematic representation of FIG. **11** illustrating movement of a unison ring of the variable geometry mechanism and showing the mechanism around turbine wheel;

[0045] FIG. **12***a* is a sectioned view through the variable geometry mechanism along line F-F of FIG. **12**;

[0046] FIG. **13** is a sectioned view similar to that of FIG. **12***a* but though a first alternative embodiment of the variable geometry mechanism of FIG. **12**;

[0047] FIG. **14** is a schematic perspective view from one end of part of a variation to the variable geometry mechanism of FIG. **13**;

[0048] FIG. **14***a* is a schematic perspective view from the opposite end of the variable geometry mechanism of FIG. **14**;

[0049] FIG. **14***b* is a schematic perspective view of a modified arrangement of the variable geometry mechanism of FIGS. **14** and **14***a*, in which the unison ring is on the same side as the guide ring;

[0050] FIG. **15** is a sectioned view similar to that of FIG. **12***a* but through a second alternative embodiment of the variable geometry mechanism;

[0051] FIG. **16** is a schematic representation of part of a third alternative embodiment of the variable geometry turbine;

[0052] FIG. **17** is a schematic representation of part of a fourth alternative embodiment of the variable geometry turbine;

[0053] FIG. **18** is a schematic representation of part of a fifth alternative embodiment of the variable geometry turbine;

[0054] FIG. **19** is a schematic representation of a variable geometry turbine in accordance with the present invention and illustrating translational movement of vanes upstream of the turbine wheel;

[0055] FIG. **20** is a schematic representation similar to that of FIG. **19** but with the vane array configured to move in a slightly different translational direction; and

[0056] FIG. **21** is a schematic representation similar to that of both FIGS. **19** and **20** with the vane array configured to move in a yet further different translational direction.

[0057] Referring now to FIGS. **1** to **8** of the drawings, the exemplary turbocharger comprises a turbine **1** joined to a compressor **2** via a central bearing housing **3**. The turbine **1** comprises a turbine housing **4** that houses a turbine wheel **5** rotatable about an axis. Similarly, the compressor **2** comprises a compressor housing **6** that houses a compressor wheel (not shown). The turbine and compressor wheels are mounted on opposite ends of a common turbocharger shaft S (FIG. **7**) which is supported for rotation about the axis in bearings B (FIG. **7**) within the bearing housing **3**.

[0058] The turbine housing **4** is provided with an exhaust gas inlet **7** and an exhaust gas outlet **8**. The inlet directs incoming exhaust gas to an annular inlet chamber, i.e. volute **9**, surrounding the turbine wheel **5** and communicating therewith via a radially extending annular inlet passageway **10**. Rotation of the turbine wheel **5** rotates the compressor wheel, which in turn draws in air through an axial inlet **11** and delivers compressed air to the engine intake (not shown) via an annular outlet volute **12**.

[0059] The turbine **1** is a variable geometry turbine in which the exhaust gas flows from the inlet chamber **9** to the outlet **8** via a variable geometry mechanism **13** that is disposed radially outboard of the turbine wheel **5**.

[0060] Referring now to FIGS. **9** and **10** as well as FIGS. **1** to **8**, the variable geometry mechanism **13** comprises a circumferential array of vanes **14** that extend across the inlet passageway **13** between a first annular guide ring **15** on one side of the passageway **13** and a second annular guide ring **16** on the other side. The vanes **14** are moveable relative to each other and with respect to guide rings **15**, **16** to vary the cross-sectional area of the inlet passageway **13** exposed to the exhaust gas and thus to control the flow through to the turbine wheel **5**, as will be described later.

[0061] The first guide ring **15** is fixed to a wall **17** of the turbine housing **4** and has a first surface, facing the inlet passageway **13**, with a plurality of elongate first guide slots **18** arranged in an annular array. Each of the first guide slots **18** is substantially linear and extends along an axis that is substantially tangential to an imaginary concentric circle on the first surface of the first guide ring **15**. In an alternative embodiment the first guide slots may be inclined to the tangential direction. In the particular embodiment shown each of the first guide slots **18** is blind i.e. its depth is such that it does not penetrate through the guide ring **15**. The second guide ring **16** is penetrated by a corresponding arrangement of elongate second guide slots **19**. At its inner periphery the second guide ring **16** has a flange **20** that extends in an axial direction away from the first ring **15** and supports a unison ring **21**, rotation of which by an actuator **22** effects movement of the vanes **14**. The unison ring **21** is guided in rotation by the flange **20** and has a plurality of slots **23**, each of which extends in a substantially radial direction and is open to the inner periphery of the ring **21**.

[0062] The actuator **22** may take any suitable form but in the embodiment shown it comprises a pneumatic actuator with a reciprocating piston rod **25** terminating in a bush **26** that is connected to a first end of a pivotal cranked arm **27** in such a manner that it permits lost motion between the arm **27** and the rod **25**. A second end of the cranked arm **27** comprises a spindle **28** that terminates in disc **29** having a surface traversed by a slot **30** for connected to the unison ring **21**.

[0063] An annular retaining plate **31** serves to retain the variable geometry mechanism **13** in the turbine housing **4** and is fixed relative to the bearing and turbine housings **3**, **4**. It is penetrated by a small bore **32** in which the spindle **28** of the cranked arm **27** is received such that its second end (disc **29**) is positioned between the retaining plate **31** and the unison ring **21**. The slot **30** (FIG. **1**) in the disc **29** receives a pin **33** that extends axially from the unison ring **21**.

[0064] In operation, reciprocal translation of the piston rod **25** causes the cranked arm **27** to rotate about the spindle **28** and therefore the disc **29**. The pin **33** is offset from the centre of rotation of the disc **29** (i.e. the axis through the spindle **28**) such that rotation of the disc **29** causes the displacement of pin **33** around the spindle **28** and relative to the slot **30**. This movement causes the unison ring **21** to rotate about its centre axis to effect movement of the vanes **14** relative to the guide rings **15**, **16** so as to increase or decrease the cross sectional area of the inlet passageway **13**

[0065] Each of the vanes **14** has an aerofoil profile with an upstream leading edge distal from the turbine wheel **5**, a downstream trailing edge proximate the outer periphery of the turbine wheel **5**, and a vane height that extends in the axial direction across the inlet passageway **10**. A first end of each vane defines a first tab **35** for receipt in a corresponding one of the first guide slots **18** in the first guide ring **15** and a second end of each vane **14** defines a second tab **36** for receipt in one of the second guide slots **19** in the second guide ring **16**. An integral pin **37** extends from each second tab **36**, passes through the respective second guide slot **19** in the second guide ring **16** and into a radial slot **23** of the unison ring **21**. Each of the first and second tabs **35**, **36** is designed to translate relative to the respective first and second guide slots **18**,**19** in which it resides by a sliding movement and may therefore be made from, or coated with, a suitable wear-resistant bearing material.

[0066] Angular displacement of the unison ring **21** about its central axis of rotation by the actuator **22** causes a corresponding angular displacement of the radial slots **23** and therefore the pivot pins **37** of the vanes **14** that reside in the slots **23**. This displacement of the pins **37** causes the vanes **14** to move relative to the guide rings **15**, **16** by virtue of a translational movement of the first and second tabs **35**, **36** in the first guide slots **18** of the first guide ring **15** and the second guide slots **19** of the second guide ring **16** respectively. At the same time, the pins **37** travel along the radial slots **23** of the unison ring **21**. The movement of the vanes **14** is illustrated in FIGS. **11** and **11***a* which depict the vanes **14** (in solid line) disposed at one extremity of their potential length of travel with the second tabs **36** shown each at an outer end of the second elongate slots **19** in the second guide ring **16**. In this disposition of the vanes **14** the first tabs **35** will similarly occupy the outer end of the first guide slots **18** in the first guide ring **15** and the spacing between each of the vanes **14** is such that the annular inlet passageway **10** has a maximum cross-sectional area. As the unison ring **21** is angularly displaced in one direction the vanes **14** are moved to the left (in the orientation of FIGS. **11** and **11***a*) as illustrated by the dotted lines. More specifically, the first and second tabs **35**, **36** translate in the first and second guide slots **18**, **19** until they occupy the inner ends thereof and, simultaneously, the pins **37** translate inwardly in the radial slots **23** in the unison ring **21**. As a result, the gap between adjacent vanes **14** is decreased and the cross-sectional area of the passageway is reduced to a minimum so as to restrict (but not preclude) the flow of exhaust gas.

[0067] The arrangement allows for accurate control of the cross-sectional area of the passageway and the vane angle with respect to the exhaust gas thus improving flow conditions and turbine efficiency. It also allows for accurate control of the trailing edge of the vane with respect to the periphery of the turbine wheel. This can be important as if the gap between the two is too small the turbine wheel blades may be subject to vibration by passing through the wakes of the vanes. If such vibration occurs over repeatedly it can lead to high cycle fatigue of the blades. On the other hand a reduction of the gap may be desirable in some circumstances to improve turbine efficiency.

[0068] A schematic representation illustrating the movement of the unison ring **21** is shown in FIGS. **12** and **12***a*. Two positions of the unison ring **21** (with slots **23**) and vanes **14** are shown relative to the turbine wheel **5**. For case of understanding the unison ring **21** is depicted with a lobe L so as to illustrate clearly the angular displacement. The positions of the lobe L, vanes **14**, unison ring **21** and slots **20** before displacement are shown in bold line whereas the respective positions (L', **14'**, **20'**) after displacement indicated by the arrow as shown in thin line.

[0069] The first guide slots **18** in the first guide ring **15** and the corresponding second guide slots **19** in the second guide ring **16** may be inclined to the tangential direction by an angle of up to 40 degrees. In such an instance the radial slots **23** in the unison ring **21** may be correspondingly inclined to the radial direction.

[0070] An alternative embodiment of the variable geometry mechanism is depicted in schematic form in FIG. **13** in which there is a single guide ring **115** axially spaced from the unison ring **121**, the rings **115**, **121** bounding the annular inlet passageway **110** on each side. In this particular embodiment the single fixed guide ring **115** has first guide slots **118** as before and the unison ring **121** has radial slots **123** that are closed at each end. It will be appreciated that in the absence of a second guide ring, the second tabs on the unison ring side may be omitted.

[0071] In a variation to the immediately preceding embodiment, flanges are provided at each end of the vanes **214** as depicted in the schematic representations of FIGS. **14** and **14***a*. In FIG. **14** the unison ring **221** is omitted for clarity and in FIG. **14***a* the guide ring **215** is omitted for the same reason. The flanges **240**, **241** may take any suitable form but in the embodiment shown they are generally rectangular and extend in a plane that is parallel to the plane of the single guide ring **215** and the unison ring **221**. In the embodiment shown, the single guide ring **215** has two circumferential arrays of first guide slots **218***a*, **218***b*, the arrays being radially offset from one another. A first flange **240** has a pair of radially spaced rectangular projections **242** for receipt in the corresponding slots **218***a*, **218***b* in the guide ring **215**, the projections being shorter in length than the length of the slots. The opposite second flange **241** has a pair of angularly offset radially extending projections **243** for receipt in the radial slots **223** defined in the unison ring **221**, the length of the radial slots being longer than the projections. In operation, rotation of the unison ring **221** causes the projections **242** on the first flanges **240** to translate in the slots **218***a*, **218***b* in the guide ring **215**, causing the flanges **240**, **241** and therefore the vanes **214** to be displaced both angularly and radially outwards, the radially outward movement being accommodated by translation of the projections **243** on the second flanges **241** in the radial slots **223** in the unison ring **221**. The flanges **240**, **241** provide stability and, in particular, reduce the risk of the vane twisting out of position and causing a jam or wear. The same general arrangement can be provided with the unison ring **221** on the same side as the guide ring **215** as depicted in FIG. **14***b*. In this embodiment the rectangular projections **242** on the rear of the first flanges **240** are supplemented with a pair of perpendicular pegs **244** that are received in the radial slots **223** of the unison ring **221**. The projections **243** on the second flanges **241** may be received in a second guide ring (not shown) or any suitable support such as, for example, slots (blind or otherwise) machined in a wall of the turbine or bearing housing.

[0072] In the embodiment of FIG. **15** both guide rings are eliminated. Instead of the first guide ring, guide slots **318** are defined in a wall **350** of the turbine housing **304** opposite the unison ring **321**, the annular inlet passageway **310** being defined between the turbine housing wall **350** and the unison ring **321**. The flanges shown in the embodiment of FIGS. **14***a*-**14***b* may be adopted on at least the side of the unison ring **321**.

[0073] The embodiment of FIGS. **1** to **10** may be similarly modified to replace the first guide ring with a suitably formed surface of the turbine housing.

[0074] In FIG. **16** an alternative embodiment is shown in which the first guide slots **418** in the first guide ring **415** or turbine housing wall are arcuate. It will be understood that in embodiments where a second guide ring is provided the guide slots will have the same form. As in the preceding embodiments, tabs on the vanes **414** slide relative to the slots **418** as the unison ring is angularly displaced. In this instance the tabs **435** are curved in the same profile as the slots **418** or may take the form of cylindrical pins or any other suitable projection. The vane **414** is depicted in thick solid line at one extremity of its travel length and thin solid line **414'** at its opposite extremity with intermediate positions being depicted in dotted line. In the embodiment shown the arcuate slot **418** has constant curvature and is convex from the perspective of the turbine axis but could equally be concave. The curvature of the slot may be configured to provide a predetermined relationship between the cross-sectional area of the annular inlet passageway and the distance (D) between the trailing edge of the vanes and the adjacent periphery of the turbine wheel. For example the distance D may increase with an increasing throat gap between adjacent vanes but the respective increases may be designed to be at a different rate. In particular a concave guide slot may be configured so that the distance D increases at a decreasing rate with increasing throat gap. Indeed the rate may decrease to a point where it is a zero or negative. Similarly a convex guide slot may be configured to provide an increase in the distance D at an increasing rate with increasing throat gap and may start at a zero or negative rate of increase.

[0075] In a modification to the embodiment of FIG. **16** slots in the unison ring may also be curved so that irrespective of the vane position the respective tabs or pins move in substantially perpendicular directions.

[0076] In the embodiment of FIG. **17** the vanes **514** may be supported in two guide slots **518***a*, **518***b* in the first guide ring **515**. In the embodiment shown the vane **514** has a pin **551**, **552** at each end. A first pin **551** proximate the trailing edge slides in a first guide arcuate slot **518***a* and a second pin **552** proximate the leading edge slides in a linear slot **518***b* that is inclined to a radius of the guide ring **515**. The vane **514** and its pins **551**, **552** are shown at one extremity of its travel in thick solid line and at the other in thin solid line **514'**,**551'**,**552'** with intermediate positions being depicted in dotted line. For the purposes of illustration only the radial slot **523** in the unison ring (not shown) is also depicted in its two positions at the travel extremities.

[0077] Any of the preceding embodiments may be provided with an array of fixed splitter vanes **655** upstream of the main vanes **614**. An example is shown in FIG. **18**. These splitter vanes **655** serve to improve flow conditions when the variable geometry mechanism is open and in embodiments where there are first and second guide rings may be used as a support that extends between them. As an alternative the splitter vanes **655** may be arranged to rotate or translate with the main vane position so as to maintain optimal flow conditions. The position of the slots **623** in the unison ring (not shown) is again depicted for ease of understanding.

[0078] The movement of the vanes may be achieved by rotation of the guide ring as well as the unison ring, the two rings being rotated in opposite directions.

[0079] The variable geometry mechanism may be assembled as a cartridge as, for example, shown in the embodiment of FIG. **10** and may be fitted from either the turbine outlet or between the bearing housing and the turbine housing. It is to be appreciated that the unison ring and actuator may be provided on the bearing housing side as depicted in FIGS. **1** to **8** or, alternatively, may be disposed on the turbine housing side.

[0080] For aerodynamic efficiency in all embodiments the slots are preferably hidden from the gas flow path by the vanes at all times.

[0081] FIGS. **19** to **21** illustrate three possible paths described by the vanes moving relative to the turbine housing **704**, **804**, **904** and wheel **705**, **805**, **905** using vane adjustment mechanisms of the types described above. In the embodiments exemplary vanes **714**, **814** or **914** are each shown in two positions: a first position where the vanes **714**, **814**, **914** are disposed such that the effective cross-section area of the inlet for the gas is relatively small and a second position in which the vanes, labelled **714'**, **814'** and **914'** respectively, are disposed such that the effective cross-section area of the inlet is relatively large. The minimum vane-to-vane distance (which is proportional to the cross section area), represented by arrows Z and Z' increases as the vanes move from the first to the second positions.

[0082] In the first position, trailing edges T of the vanes **714**, **814**, **914** are proximate the circumference C swept by the outer periphery of the turbine wheel **704**, **804**, **904** as it rotates. This distance is represented by arrow Y. In the second position the trailing edges T' are relatively distal as represented by distance Y'. In the arrangement shown in FIG. **19** the vanes translate in a straight path as indicated by arrowed line X between the positions indicated by **714** and **714'**. The movement of the vanes between the first and second positions serves to vary the swirl angle of the gas for a given turbine pressure ratio (that is the pressure ratio across the vanes and turbine wheel considered as a single unit). In the first position **714** the vanes are disposed such that they impart on the gas a first swirl angle ø which is measured at the circumference C of the turbine wheel relative to a radial plane that intersects the rotation axis of the turbine wheel. By the time the vanes have translated to the position indicated by **714'** the swirl angle ø' has decreased (i.e. is has moved closer towards radial plane from a plane tangential to the circumference C). The arrangement helps to mitigate turbine wheel blade vibration and the resulting metal fatigue.

[0083] The arrangements shown in FIGS. **20** and **21** are very similar to that of FIG. **19** except that the vanes translate in a slightly different path as a result of slightly different configurations of the guide slots **18**,**19**, **218***a*, **218***b*, **418** etc.

In FIG. **20** the path has a slight inward curve whereas in FIG. **21** the path has a slight outward curve similar to that shown in FIG. **16**. The minimum vane to vane distance, the distance of the trailing edge of the vanes to the circumference and the swirl angles are given the same references as in FIG. **19**.

[0084] While the invention has been illustrated and described in detail in the drawings and foregoing description, the same is to be considered as illustrative and not restrictive in character, it being understood that only the preferred embodiments have been shown and described and that all changes and modifications that come within the scope of the inventions as defined in the claims are desired to be protected. It should be understood that while the use of words such as preferable, preferably, preferred or more preferred utilized in the description above indicate that the feature so described may be more desirable, it nonetheless may not be necessary and embodiments lacking the same may be contemplated as within the scope of the invention, the scope being defined by the claims that follow. In reading the claims, it is intended that when words such as "a," "an," "at least one," or "at least one portion" are used there is no intention to limit the claim to only one item unless specifically stated to the contrary in the claim. When the language "at least a portion" and/or "a portion" is used the item can include a portion and/or the entire item unless specifically stated to the contrary.

1. A variable geometry turbine comprising:

a housing defining a chamber within which a turbine wheel is mounted for rotation about a turbine axis such that its outer periphery substantially describes a swept circumference;

the chamber having a gas inlet disposed radially outboard of an outer periphery of said turbine wheel;

a plurality of vanes arranged around the turbine axis, each vane having a vane height extending between a first end and a second end in a direction across the inlet in a substantially axial direction and each vane being movable so as to adjust the effective cross-section area of the inlet between a first position in which the area of the inlet is a minimum and a second position in which the area of the inlet is a maximum;

at least one guide member having a plurality of first guide tracks for engagement with the first ends of the vanes;

a vane actuator for effecting translational movement of the plurality of vanes relative to the housing between the first and second positions, the vane actuator having a plurality of actuation tracks for engagement with the plurality of vanes, the vane actuator being rotatably disposed in the housing such that rotation of the vane actuator induces sliding translation of each of the plurality of vanes relative to a respective first guide track in a first direction and sliding translation of each of the plurality of vanes relative to the respective actuation track in a second direction, the second direction being different to the first direction;

wherein in the first position the vanes are disposed such that at a given turbine pressure ratio they direct the gas to the turbine wheel such that it has a first swirl angle at the swept circumference of the turbine wheel and in the second position the vanes are disposed such that at the same turbine press ratio they direct the gas to the turbine wheel such that it has a second swirl angle at the swept circumference, the first swirl angle being greater than the second swirl angle.

2. A variable geometry turbine according to claim **1**, wherein the first ends of the plurality of vanes have at least one projection and the plurality of first guide tracks are in the form of first guide slots, the at least one projection of each vane being received in a respective first guide slot.

3. A variable geometry turbine according to claim **1**, wherein the plurality of first guide slots extend in a substantially tangential direction.

4. A variable geometry turbine according to claim **1**, wherein the plurality of actuation tracks in the vane actuator are in the form of slots.

5. A variable geometry turbine according to claim **4**, wherein the actuation tracks extend in a substantially radial direction.

6. A variable geometry turbine according to claim **1**, wherein the guide member and the vane actuator are spaced apart in the axial direction, the plurality of vanes being disposed between them.

7. A variable geometry turbine according to claim **6**, wherein the second ends of the vanes each have at least one projection and the actuation tracks are in the form of slots, the at least one projection of the second ends being received in a respective slot in the vane actuator.

8. A variable geometry turbine according to claim **1**, wherein the guide member and the vane actuator are disposed at the first end of the vanes.

9. A variable geometry turbine according to claim **1**, wherein the guide member is defined by a wall of the turbine housing.

10. A variable geometry turbine according to claim **1**, wherein the guide member is annular.

11. A variable geometry turbine according to claim **1**, wherein there is provided a first guide member having the plurality of first guide tracks and a second guide member spaced apart from the first guide member in an axial direction and having a plurality of second guide tracks for engagement with the second end of the plurality of vanes.

12. A variable geometry turbine according to claim **1**, wherein the plurality of vanes have a flange at one or both of the first and second ends.

13. A variable geometry turbine according to claim **12**, wherein the vane projections extend from the flanges at each end.

14. A variable geometry turbine according to claim **1**, wherein the plurality of vanes each have a pair of projections at a first end for receipt in the first guide tracks.

15. A variable geometry turbine according to claim **14**, wherein the pair of guide tracks are substantially identically shaped.

16. A variable geometry turbine according to claim **14**, wherein the pair of guide tracks have different profiles.

17. A variable geometry turbine according to claim **1**, wherein the vane actuator is a substantially annular unison ring.

18. A variable geometry turbine according to claim **1**, wherein the first guide tracks are substantially linear.

19. A variable geometry turbine according to claim **11**, wherein the second guide track are substantially linear.

20. A variable geometry turbine according to claim **1**, wherein the vanes define trailing edges proximate the turbine wheel and in the first position the trailing edges of the vanes are at a first distance from the turbine wheel swept circumference, in the second position the trailing edges of the vanes are at a second distance from the swept circumference, the first distance being shorter than the second distance.

21. A variable geometry turbine according to claim **1**, wherein the plurality of vanes are movable in unison.

22. A variable geometry turbine according to claim **1**, wherein the vanes translate without pivoting about a fixed point.

23. A variable geometry turbine according to claim **1**, wherein all of the vanes disposed around the turbine axis are movable between the first and second positions.

24. A turbocharger comprising a compressor driven by an exhaust gas variable geometry turbine according to claim **1**.

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