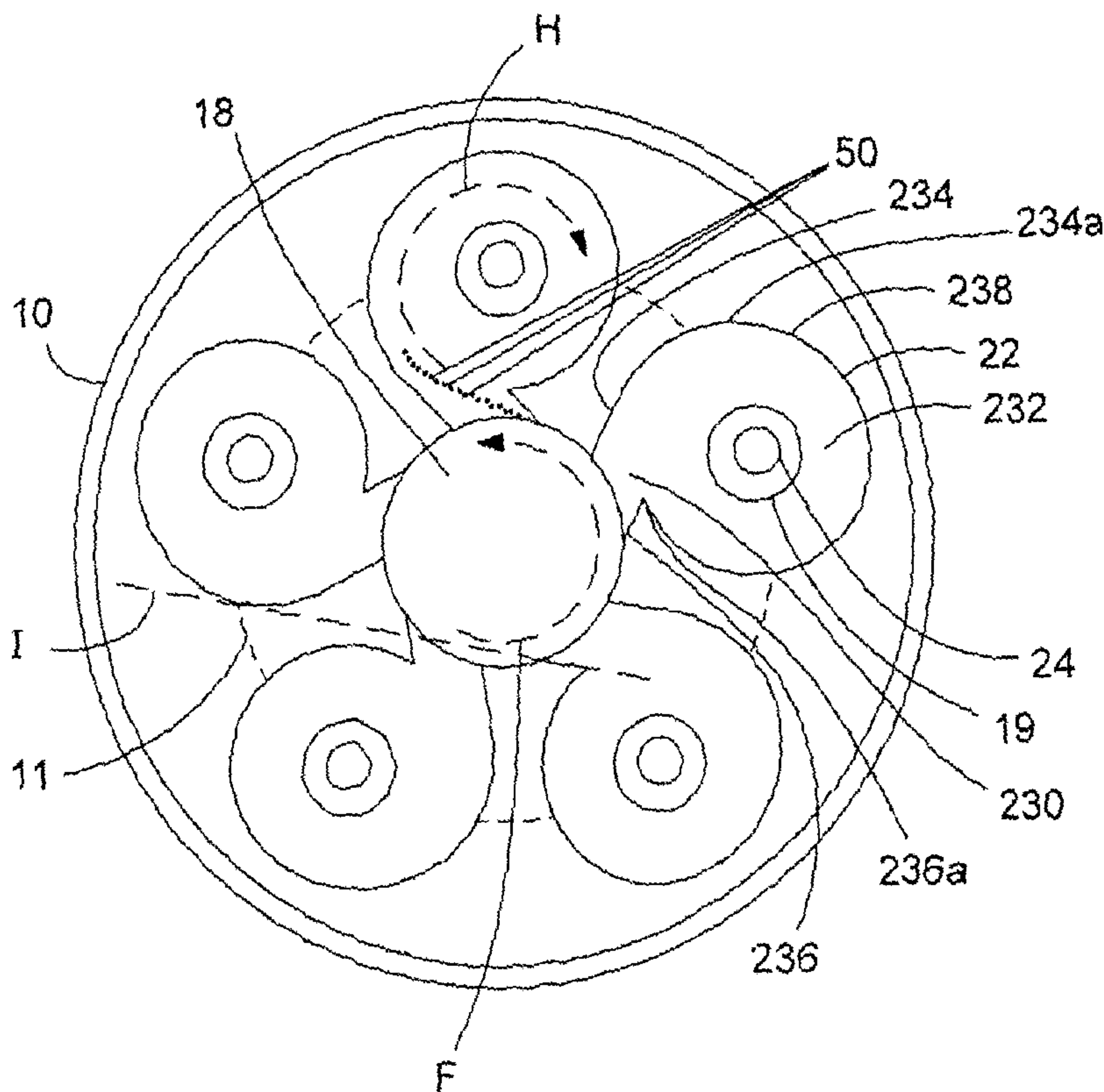




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(54) Titre : PROCÉDE ET APPAREIL POUR SEPARER UN CATALYSEUR AU MOYEN D'UN CYCLONE DANS UN PROCESSUS DE CRAQUAGE CATALYTIQUE FLUIDE
 (54) Title: PROCESS AND APPARATUS FOR THE SEPARATION OF THE CATALYST USING A CYCLONE IN A FCC PROCESS



(57) Abrégé/Abstract:

An apparatus and process for the separation of solids from gases in a mixture improves separation efficiency by imparting a swirl motion to the mixture in a first angular direction to centripetally separate the heavier solids from the lighter gases in conduit and orienting the inlet of the cyclone such that trajectory of the mixture is away from the center of the cyclone. The desired trajectory

(57) **Abrégé(suite)/Abstract(continued):**

may be gained by imparting a opposite swirling angular direction to the mixture in a separation vessel with respecto to the cyclone or having the cyclone arranged tangentially with the vessel so that the cyclone and separation vessel share a common tangential sidewall. The apparatus and method incorporates a greater proportion of the mixture entering the cyclone into its vortex to further enhance separation between the solids and gases. Further separation efficiency is added by tangentially directing the mixture into the cyclone.

**PROCESS AND APPARATUS FOR THE SEPARATION OF
THE CATALYST USING A CYCLONE IN A FCC PROCESS.**

BACKGROUND OF THE INVENTION

[0001] This invention relates to the separation of particulate catalyst materials from gaseous materials in an FCC process.

5 [0002] Cyclonic methods for the separation of solids from gases are well known and commonly used in the hydrocarbon processing industry where particulate catalysts contact gaseous reactants to effect chemical conversion of the gas stream components or physical changes in the particles undergoing contact with the gas stream.

[0003] The FCC process presents a familiar example of a process that uses gas
10 streams to contact a finely divided stream of catalyst particles and effects contact between the gas and the particles and that benefits from efficient separation of particulate catalyst from product vapors. Downstream filtration methods or additional separation devices must remove catalyst particles that the FCC unit fails to recover. Unrecovered catalyst from the FCC process represents a two-fold loss. The catalyst must be replaced,
15 representing a material cost, and catalyst lost may cause erosion to downstream equipment. Accordingly, methods of efficiently separating particulate catalyst materials from gaseous fluids in an FCC process are of great utility.

[0004] Discharge of the gaseous fluids from the FCC reaction conduit begins separation of particulate catalyst solids. The most common method of separating
20 particulate solids from a gas stream uses centripetal separation. Well known centripetal separators impart a tangential velocity to gases containing entrained solid particles that forces the heavier solids particles outwardly away from the lighter gases for upward withdrawal of gases and downward collection of solids.

[0005] US-A-5,584,985 B1 discloses initial quick separation on discharge from the reaction conduit by discharging feed and catalyst particles from a riser conduit into a separation vessel through an arcuate, tubular swirl arm to impart a helical motion to the gases and particulate catalyst. The swirling, helical motion of the materials in the separation vessel effect an initial separation of the particulate catalyst from the gases. The swirl motion of the mixture continues while it rises up the gas recovery conduit. At the end of the gas recovery conduit cyclones withdraw the mixture to further separate the particulate catalyst from the gases. This arrangement is known as the UOP Vortex Separation System (VSSSM).

10 [0006] Cyclones usually comprise a tangential inlet to the outside of a cylindrical vessel that forms an outer wall of the cyclone. The cyclone entry and the inner surface of the outer wall cooperate to create a spiral flow path or vortex of the gaseous materials and catalyst in the cyclone. The centripetal acceleration at the exterior of the vortex causes catalyst particles to migrate towards the outside of the barrel while the gaseous materials enter an interior of the vortex for eventual discharge through an upper outlet. The heavier catalyst particles accumulate on the side wall of the cyclone barrel and eventually drop to the bottom of the cyclone and out via an outlet and a dipleg conduit for recycle through the FCC apparatus.

Arranging cyclones in a vessel requires clearance between cyclones to permit adequate access for installation and for maintenance purposes. Clearance between cyclones becomes a greater consideration when more cyclones are installed in a vessel.

[0007] Accordingly, it is an object of the present invention to improve the efficiency of separating particulate solids from vapors in an FCC unit. It is a further object of the present invention to further improve such efficiency of separation in an FCC unit that utilizes a

VSSSM with one or more cyclones. An additional object of the present invention is to assure adequate clearance between cyclones in a containing vessel.

BRIEF SUMMARY OF THE INVENTION

[0008] It has now been discovered that orienting the angular direction of a swirl motion
5 from an initial separation vessel such as a VSSSM to direct it away from the center of the
cyclone enhances the separation efficiency. To accomplish this the direction of swirl in the
vessel may be counter the angular direction of a swirl motion in a downstream cyclone. The
same objective may be accomplished with a same direction of swirl in the vessel and the
cyclone as long the cyclone inlet intersects the vessel tangentially such that the particles
10 from vessel enter the cyclone along a parallel trajectory with cyclone inlet centerline.
When the swirl motions in the VSSSM and the cyclones coincide and the cyclone inlet does
not receive the mixture tangentially, less contact occurs between the mixture entering the
cyclone and the interior surface of the outer wall that imparts the swirl motion to the
mixture. Instead, the mixture tends to encounter a center of the cyclone containing the inlet
15 to the vapor outlet conduit. Consequently, some of the mixture entering the cyclone may
exit the cyclone before it receives a swirl motion from the outer wall and exits the cyclone
with minimal further separation of solid particles from the gaseous vapors. By directing the
flow from the vessel in a direction parallel to outward from the centerline of the cyclone
inlet the outer cyclone wall is more likely to impart a swirl motion to the mixture before it
20 contacts the center of the cyclone. Accordingly, greater separation efficiency results. For
co-direction of the swirl angle in the vessel and cyclone the cyclone inlet requires a
tangential connection to the vessel to achieve the desired direction of mixture entry into the
cyclone. When counter-directing the swirl motions in the cyclone and the vessel either a
radial or tangential cyclone orientation with respect to the vessel can achieve the desired

mixture entry direction for the cyclone. To counter-direct the swirl motions a VSSSM orients a swirl arm so that the opening at the end of the swirl arm angularly faces toward the wall of the inlet to the cyclone that is contiguous with the curved wall of the cyclone. In this manner the VSSSM swirl arm outlet directs the mixture in the direction of the cyclone outer wall or its contiguous surface of the cyclone inlet. With counter directed swirl motion further efficiency comes from tangentially configuring the cyclone inlet with one side upstream of the cyclone vortex and the VSSSM vortex and the opposite side of the cyclone inlet downstream of the cyclone and VSSSM vortices.

Accordingly, in one embodiment this invention is process for the fluidized catalytic cracking of a hydrocarbon feedstock. The process passes a hydrocarbon feedstock and solid catalyst particles into a reaction conduit to produce a mixture of solid catalyst particles and gaseous fluids. Inducing the mixture of the catalyst particles and gaseous fluids to swirl in an angular direction within a separation vessel decreases the catalyst particle concentration and increases the gaseous fluids concentration in said mixture. The vessel tangentially casts the mixture from the vessel into at least one cyclone through a cyclone inlet having an upstream side and a downstream side with respect to the angular direction of the swirl in the vessel. According to the invention the angular direction of swirl casts the mixture tangentially into the cyclone inlet in a direction such that a tangent to the vessel projecting from an intersection point of the upstream cyclone inlet with the vessel projects into the cyclone parallel to the cyclone inlet or away from the center of the cyclone. The mixture may be induced to swirl in an angular direction in the cyclone that is counter to the angular direction in the vessel or may swirl in the same direction in the cyclone or the vessel but enter the cyclone tangentially.

[0009] In another embodiment, the present invention is an apparatus for the fluidized catalytic cracking of a hydrocarbon feedstock. The apparatus comprises a reaction conduit for contacting a hydrocarbon feedstock and solid catalyst particles to produce a mixture of solid catalyst particles and gaseous fluids. The reaction conduit has a swirl exit configured to induce the solid catalyst particles and gaseous fluids to swirl in a first angular direction in vessel. A cyclone in communication with the swirl exit has a swirl inducing outer wall that curves to induce the solid catalyst particles and gaseous fluids to swirl in a second angular direction and a cyclone inlet that extends tangentially from the outer wall through a tangential wall. The cyclone inlet intersects the vessel such that the first swirl direction casts the mixture into the cyclone in a direction the parallel to or toward the tangential wall of the cyclone inlet. The reaction conduit may have a curved tubular swirl arm connective with the reaction conduit and the swirl arm has a curved outer wall, wherein the swirl arm curves in an angular orientation counter to the angular orientation in which the outer wall of the cyclone curves.

15

BRIEF DESCRIPTION OF THE DRAWINGS

- [0010] FIG. 1 is a schematic cross-sectional view of an FCC unit.
- [0011] FIG. 2 is a cross-section of FIG. 1 taken along segment A-A.
- [0012] FIG. 3 is a cross-section of FIG. 1 taken along segment B-B.
- [0013] FIG. 4 is a partial view of FIG. 2 showing the flow path of particulate material when the swirl motions are the same.
- [0014] FIG. 5 is an alternative cross-section of FIG. 1 taken along segment B-B.
- [0015] FIG. 6 is a partial view of FIG. 2 showing the flow path of particulate material when the swirl motions are countered.
- [0016] FIG. 7 is a further alternative cross-section of segment A-A in FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENT

[0017] FIG. 1 is the schematic illustration of an FCC unit that will serve as a basis for illustrating several embodiments. Two alternative cross-sections are taken from segment A-A of FIG. 1 which are FIGS. 2 and 7. Moreover, two alternative cross-sections are taken from segment B-B which are FIGS. 4 and 6. The FCC unit includes a separation arrangement in a reactor vessel 10. A conduit in the form of a reactor riser 12 extends upwardly through a lower portion of the reactor vessel 10 in a typical FCC arrangement. The central conduit or reactor riser 12 preferably has a vertical orientation within the reactor vessel 10 and may extend upwardly through the bottom of the reactor vessel or downwardly from the top of the reactor vessel. Reactor riser 12 terminates in a separation vessel 11 at a swirl exit in the form of a swirl arm 14. The swirl arm 14 is a curved tube that has an axis of curvature that is parallel to the reactor riser 12. (See FIG. 4). The swirl arm 14 also has one end connected to the reactor riser 12 and another open end comprising a discharge opening 16. Swirl arm 14 discharges a mixture of gaseous fluids comprising cracked product and solid catalyst particles through the discharge opening 16. Tangential discharge of gases and catalyst from the discharge opening 16 produces a swirling helical motion about the interior of separation vessel 11. Centripetal acceleration associated with the helical motion forces the heavier catalyst particles to the outer portions of separation vessel 11. Catalyst particles from discharge openings 16 collect in the bottom of separation vessel 11 to form a dense catalyst bed 17. The gases, having a lower density than the solid catalyst particles, more easily change direction and begin an upward spiral with the gases ultimately traveling into a gas recovery conduit 18 through an inlet 20. The gases that enter gas recovery conduit 18 through inlet 20 will usually contain a light loading of catalyst particles. Inlet 20 recovers gases from the discharge openings 16 as well as stripping gases from a stripping section 27. The loading

of catalyst particles in the gases entering gas recovery conduit 18 are usually less than 16 kg/m³ (1 lb/ft³) and typically less than 2 kg/m³ (0.1 lb/ft³). The swirl motion imparted by the swirl arm 14 continues in the same angular direction up through the gas recovery conduit 18. Gas recovery conduit 18 passes the separated gases into cyclones 22 that
5 effect a further removal of catalyst particulate material from the gases in the gas recovery conduit 18. Cyclones 22 create a swirl motion inside the cyclones to establish a vortex that separates solids from gases. A product gas stream, relatively free of catalyst particles, exits the cyclones 22 through vapor outlets 24 and outlet pipes 49. The product stream then exits the reactor vessel 10 through outlet 25. Catalyst solids recovered by
10 cyclones 22 exit the bottom of the cyclone through hoppers 19 and diplegs 23 and pass to a lower portion of the reactor vessel 10 where it forms a dense catalyst bed 28 outside the separation vessel 11. Catalyst solids in dense catalyst bed 28 enter a stripping section 27 through windows 26. Catalyst solids pass downwardly through the stripping section 27. A stripping fluid, typically steam, enters a lower portion of stripping section 27 through
15 at least one distributor 29. Counter-current contact of the catalyst with the stripping fluid through a series of stripping baffles 21 displaces product gases from the catalyst as it continues downwardly through the separation vessel 11. Stripped catalyst from stripping section 27 passes through a conduit 31 to a catalyst regenerator 37 that regenerates the catalyst by high temperature contact with an oxygen-containing gas by oxidizing coke
20 deposits from the surface of the catalyst. Following regeneration, catalyst particles enter the bottom of reactor riser 12 through a conduit 33 where a fluidizing gas from a distributor 35 pneumatically conveys the catalyst particles upwardly through the riser 12. As the mixture of catalyst and conveying gas continues up the riser 12, nozzle 40 injects feed into the catalyst, the contact of which vaporizes the feed to provide additional gases
25 that exit through discharge openings 16 in the manner previously described.

[0018] FIG. 2 illustrates the cyclones 22 in more detail by a cross-sectional view taken along segment A-A in FIG. 1. Each cyclone 22 comprises a radial cyclone inlet 30 and a barrel chamber 32. A vapor outlet 24 disposed in the center of the barrel chamber 32 provides for the exit of product gases along with only fine amounts of particulate material from the cyclone 22. Hopper 19 provides for the discharge of particulate material from the cyclone 22 into the dense catalyst bed 28 as described with respect to FIG. 1. The radial cyclone inlet 30 is defined by a long, straight sidewall 34 that provides a tangential wall of the cyclone inlet. The sidewall 34 preferably has a continuous gradual transition 34a that provides a continuous curve into the outer wall 38. At an abrupt transition 36a a short straight sidewall 36 acutely intersects curved outer wall 38 which defines the barrel chamber 32 of the cyclone 22. The radial cyclone inlet 30 to the cyclones 22 radially exits from the gas recovery conduit 18. Radial exit from the gas recovery conduit 18 to the cyclone 22 is generally characterized in that a mid-line "C" laterally bisecting radial cyclone inlet 30 where it exits gas recovery conduit 18 would substantially intersect the cross-sectional center of the gas recovery conduit 18. In operation, a mixture of gases and particulate material exits gas recovery conduit 18 into the radial cyclone inlet 30 of cyclone 22. The long, straight sidewall 34 and the curved outer wall 38 provide a continuous surface which imparts a swirl motion to the mixture entering the cyclone 22 to generate the vortex which separates the particulate material from the gases.

[0019] The orientation of curvature of swirl arms 114 is shown in FIG. 3. A mixture containing particulate material and gaseous fluids ascending through reactor riser 12 exit the reactor riser 12 through swirl arms 114 out discharge opening 16 swirling in a clockwise angular direction. As the mixture exits the separation vessel 11 and transports

through gas recovery conduit 18, the mixture will retain the same swirl motion in a clockwise angular direction.

[0020] FIG. 4 shows how particulate material 50 radially exiting the gas recovery conduit 18 enters the cyclone 22. Only one cyclone is shown in FIG. 4 for purposes of simplicity. A swirl motion of clockwise angular direction "D" of the mixture containing particulate material 50 in gas recovery conduit 18 is generated by swirl arms 14 having the orientation of curvature shown in FIG. 3. The orientation of curvature of swirl arm 14 is the angular direction it defines from inlet to outlet. Straight sidewall 34, gradual transition 34a and the curved outer wall 38 impart a swirl motion of clockwise angular direction "E" to the mixture in cyclone 22. When the swirl arms 114 have the same orientation of curvature as the orientation of curvature of the cyclones 22, they impart the same swirl motions of clockwise angular direction "D" in the gas recovery conduit 18 and "E" in the cyclone 22, as in the prior art. Consequently, the particulate material 50 entering the cyclone has a tendency to approach the vapor outlet 24 instead of following the interior surface of the curved outer wall 38 to generate the swirl motion desired. Consequently, it is believed that some of the particulate material 50 exits through the vapor outlet 24 before incorporation into a vortex which separates the particulate material 50 from the gases thereby diminishing the separation efficiency of the gas from the particulate material.

[0021] Tangent line J in Figure 4 more fully defines the undesired direction of mixture flow that characterizes the prior art. Tangent line J projects along a tangent to the vessel wall of gas recovery conduit 18 that starts at point L where sidewall 34 intersects conduit 18. With respect to the direction of swirl in the conduit 18, sidewall 34 forms the upstream side of cyclone inlet 30. The described configuration of figure 4 projects tangent line J toward the center of the cyclone 22 which coincides with vapor outlet 24.

[0022] To effect the objects of this invention Figure 4 also shows a rearrangement of vessel wall 34 to 34'. Moving the sidewall 34 to position 34' shifts the upstream intersection point L to point L' so that wall 34' defines a tangent from intersection point L' and although not shown the shifting of inlet 30 would give the cyclone inlet 30 a centerline parallel to line 34'. Thus a tangent drawn along line 34' does not project toward the center of cyclone of 22 and but is now parallel to the centerline of the cyclone inlet so that the trajectory of the entering mixture is parallel to the cyclone inlet.

[0023] The object of the invention may also be achieved by reversing the direction of swirl in the vessel. FIG. 5 shows the orientation of curvature of the swirl arms 14 counter to that of the swirl arms in FIG. 4 and counter to the orientation of curvature of the cyclone 22 according to an embodiment of the present invention. The same reference numeral designates elements common to both FIGS. 3 and 5. The discharge openings 16 in FIG. 5 face oppositely to discharge openings 16 in FIG. 3. Consequently, the orientation of curvature of the swirl arms 14 is counter to the orientation of curvature of the cyclone 22. FIG. 5 shows four swirl arms 14. More or less swirl arms can be used.

[0024] FIG. 6 demonstrates the interaction between the counter swirling angular directions in the gas recovery conduit 18 and the cyclone 22. The mixture exiting discharge openings 16 in the swirl arms 14 in FIG. 5 will swirl in a counter-clockwise angular direction "F". The mixture will continue to swirl in a counter-clockwise motion as the mixture ascends the gas recovery conduit 18. However, the swirl motion in the cyclones 22 shown in FIG. 2 will be in a clockwise angular direction "E". As the mixture containing particulate material 50 enters radial cyclone inlet 30 of the cyclone 22 the angular momentum of the mixture sidewall 34 instead of the center of the barrel chamber 32. The long, straight sidewall 34 and curved outer wall 38 are consequently able to impart a swirl motion of clockwise angular direction "E" to more of the mixture, thereby

incorporating more of the mixture in the vortex that separates the particulate material 50 from the gases. The heavier particulate material 50 swirls at the curved outer wall 38 of the cyclone 22 where it eventually falls down to the hopper 19 to enter dipleg 23 and eventually join the dense catalyst bed 28. That the swirl arms 14 swirl the mixture in a counter-clockwise angular direction and the cyclones swirl the mixture in a clockwise angular direction is not a limiting factor, but the counter relationship between the angular directions of swirl motion from the swirl arms 14 and the cyclones 22 but is an useful way to avoid impingement of particles with central portions of the cyclone.

[0025] Looking again at the trajectory of particle flow along a tangent. FIG. 5 shows a tangent line M projecting tangentially from conduit 18 and originating from point N where the sidewall 36, now the upstream wall of cyclone inlet 30, intersects with conduit 18. The end of tangent line M projects toward the outer portion of inlet 30, against sidewall 34, and away from the center of cyclone 22. Thus the end of tangent line M is away from the center of cyclone 22.

[0026] FIG. 7 depicts a further embodiment of the present invention that provides substantially tangential exit to the cyclones from the gas recovery conduit 18 and in which the swirl motion of counter-clockwise angular direction "F" of the mixture in the gas recovery conduit 18 is counter to the swirl motion of clockwise angular direction "H" induced in the cyclones. FIG. 7 is taken as an alternative cross-section of FIG. 1 along segment A-A. The reference numeral for each element in FIG. 7 related to an inlet that is configured differently from a corresponding element in FIG. 2 will be designated by adding 200 to the reference numeral in FIG. 2. Other elements common to both FIGS. 2 and 7 will retain the same reference numeral. The section at segment B-B of FIG. 1 that corresponds to the embodiment illustrated in FIG. 7 is illustrated in FIG. 5. Swirl arms 14 impart a swirl motion of counter-clockwise angular direction "F" to the mixture

containing particulate material 50 discharging from the reactor riser 12. This counter-clockwise angular direction "F" of swirl motion continues as the mixture travels up gas recovery conduit 18. The mixture exits the gas recovery conduit 18 through cyclone inlets 230 which are substantially tangential to the gas recovery conduit 18. The mixture enters each cyclone 22 through a tangential cyclone inlet 230 defined by long, straight sidewall 234 and short, straight sidewall 236. A line "I" coplanar or co-linear with the short, straight sidewall 236 is substantially tangential to a cross-sectional profile of the gas recovery conduit 18. The short, straight sidewall 236 may be spaced slightly inwardly of tangent to facilitate its welding to the gas recovery conduit 18. This arrangement permits installation of more cyclones 22 in the reactor vessel 10 with greater clearance between each of the cyclones 22. The long, straight sidewall 234 is contiguous and has a continuous, gradual transition 234a with a curved outer wall 238 which defines the barrel chamber 232 of the cyclone 22. The short, straight sidewall 236 has an abrupt, acute transition 236a with the curved outer wall 238. A mixture with a greater concentration of particulate material 50 than that entering the cyclone 22 exits downwardly through hopper 19 while a mixture with a greater concentration of gaseous fluids than that entering the cyclone 22 exits upwardly through vapor outlet 24. The long, straight sidewall 234 and curved outer wall 238 cooperate to impart a swirl motion to the mixture entering cyclone 22, thereby establishing a vortex which separates the particulate material 50 from the gases. In this embodiment, the swirl motion of counter-clockwise angular direction "F" imparted by the swirl arms 14 from the reactor riser 12 is counter to a clockwise angular direction "H" of swirl motion imparted by the cyclones 22. Consequently, the particulate material 50 in the mixture is more likely to first encounter the long, straight sidewall 234 and/or curved outer wall 238 and be subjected to the swirl motion of the vortex than it would be to first encounter the center of the cyclone 22 and

be discharged from the cyclone with gases through the vapor outlet 24. Accordingly, because greater proportions of the mixture are likely to be subject to the swirl motion than tending toward the center of the cyclone, greater efficiency in separation is realized. This arrangement also provides counter angular directions of swirl motion in the gas recovery conduit 18 and the cyclones 22, which formerly agreed, by modifying the orientation of the cyclones 22 instead of the swirl arms 114.

EXAMPLE I

[0027] Computational flow dynamics (CFD) modeling using a FLUENT program was performed to study separation efficiencies for three sets of conditions. The following was assumed for all three sets of conditions: the minimum catalyst size was 40 micrometers, the gas density was 2.75 kg/m^3 , the gas velocity was 0.02 c.p., the velocity of the mixture exiting each swirl arm was 20.8 m/sec, the pressure was 299 kPa and the temperature was 549°C.

[0028] The first set of conditions involved a model where radial cyclone inlets 30 to the cyclones 22 were disposed with respect to the gas recovery conduit 18 as shown in FIG. 2 and the swirl arms 114 were disposed as in FIG. 3. This model focused on the case where the angular direction of the swirl motion imparted by the swirl arms was the same as the angular direction of the swirl motion imparted by the cyclones 22 as shown in FIG. 4. The CFD modeling indicated that in this model, 21% of the mixture entering the cyclone veered toward the center of the cyclone instead of veering toward the periphery of the cyclone to join the vortex to further separate the gases from the solids, representing a loss in efficiency.

[0029] A second set of conditions had the same cyclone configuration shown in FIG. 2 as in the previous model. However, the swirl arms 14 were oriented as shown in FIG.

5, so that the angular direction of swirl motion generated by the swirl arms 14 was counter to the angular direction of swirl motion generated by the cyclones 22 as shown in FIG. 6. Modeling indicated that only 10% of the mixture entering the cyclone veered toward the center of the cyclone where the vapor outlet is disposed without veering toward the vortex for further separation.

EXAMPLE II

[0030] A reactor vessel was modeled with five cyclones. Inlets to the cyclones comprised a long wall having a continuous, gradual transition to curved outer wall defining the cyclone barrel and a short, straight sidewall which had an abrupt, acute transition to the curved outer wall. The long, straight sidewall was disposed substantially tangential to the gas recovery conduit which transports the mixture from a reactor riser to the cyclones. In an effort to prevent the mixture entering the cyclone from bypassing the vortex therein, the cyclone inlet was made a relatively long 45.7 cm (18 inches). The clearance between cyclones at their largest distance of separation was only 10.7 cm (4.2 inches).

[0031] In a separate model, five cyclones were installed in a reactor vessel similar to the previous model with the exception that the length of the short, straight sidewall was only 32.0 cm (12.6 inches) and the short, straight sidewall was disposed substantially tangentially to the gas recovery conduit as shown in FIG. 7. Accordingly, the orientation of curvature of the cyclones in the second model was counter to the orientation of curvature of the cyclones in the first model. However, in the second model, the clearance between cyclones at their largest distance of separation was 45.7 cm (18 inches). Accordingly, by reversing the orientation of the cyclones, the clearance between cyclones increases by just under 300%. Hence, the second model provides more flexibility in

arranging a given number of cyclones in a reactor vessel in addition to reversing an orientation of curvature of the cyclones to counter the orientation of curvature of the swirl arms at an exit of a reactor conduit to enhance separation efficiency.

[0032] The first set of conditions involved a model where radial cyclone inlets 30 to 5 the cyclones 22 were disposed with respect to the gas recovery conduit 18 as shown in FIG. 2 and the swirl arms 114 were disposed as in FIG. 3. This model investigated a case where the swirl arms imparted the same as the angular direction as the cyclones 22 shown in FIG. 4 and the cyclone inlet sidewall corresponds to that depicted by numeral 34. The CFD modeling indicated that in this model, 21% of the mixture entering the 10 cyclone veered toward the center of the cyclone instead of veering toward the periphery of the cyclone to join the vortex to further separate the gases from the solids, representing a loss in efficiency.

[0033] A second set of conditions had the same cyclone configuration shown in FIG. 2 as in the previous model. However, the swirl arms 14 were oriented as shown in FIG. 15 5, so that the angular direction of swirl motion generated by the swirl arms 14 was counter to the angular direction of swirl motion generated by the cyclones 22 as shown in FIG. 6. Modeling indicated that only 10% of the mixture entering the cyclone veered toward the center of the cyclone where the vapor outlet is disposed without veering toward the vortex for further separation.

CLAIMS:

1. A process for the fluidized catalytic cracking of a hydrocarbon feedstock comprising:
passing a hydrocarbon feedstock and solid catalyst particles into a reaction
5 conduit to produce a mixture of solid catalyst particles and gaseous fluids;
inducing said mixture of said catalyst particles and gaseous fluids to swirl in an
angular direction within a separation vessel to decrease the catalyst particle
concentration and increase the gaseous fluids concentration in said mixture;
and
10 tangentially casting the mixture from the vessel into at least one cyclone through
a cyclone inlet having an upstream inlet wall and a downstream inlet wall
with respect to the angular direction of swirl in the vessel,
characterized in that the angular direction of swirl casts the mixture tangentially
into the cyclone inlet in a direction such that a tangent to the vessel projecting
15 from an intersection point of the upstream inlet wall with the vessel projects
into the cyclone in a direction away from the center of the cyclone.
2. The process of claim 1 wherein the tangent projects along a line parallel to the
centerline of the cyclone inlet.
3. The process of claim 1 wherein the cyclone receives the mixture tangentially
20 from the separation vessel into the cyclone inlet.
4. The process of any of claims 1 to 3 wherein the angular direction of swirl in the
vessel is opposite to the angular direction of swirl in the cyclone.
5. The process of claims 1 to 3 wherein said mixture exits said reaction conduit
through a swirl arm to induce swirling in said first angular direction.

6. The process of any of claims 1 to 3 wherein said mixture is transported from said reaction conduit to said vessel and said vessel comprises a gas recovery conduit that communicates directly with said cyclone.

5 7. An apparatus for the fluidized catalytic cracking of a hydrocarbon feedstock comprising:

a reaction conduit for contacting a hydrocarbon feedstock and solid catalyst

particles to produce a mixture of solid catalyst particles and gaseous fluids,

said reaction conduit having a swirl exit configured to induce the solid

catalyst particles and gaseous fluids to swirl in a first angular direction;

10 a separation vessel for receiving the mixture from the reaction conduit and

maintaining the swirl of the mixture in the first angular direction; and

a cyclone in communication with said swirl exit, said cyclone having a swirl

inducing outer wall that induces the solid catalyst particles and gaseous fluids

to swirl in a second angular direction and having a cyclone inlet that extends

15 tangentially from the outer wall into an extended tangential wall,

characterized in that the cyclone inlet intersects the vessel such that the first swirl

direction casts the mixture into the cyclone in a direction parallel to or toward

the tangential wall of the cyclone inlet.

8. The apparatus of claim 7 wherein the swirl exit comprises a tubular swirl arm
20 having one end connective with the reaction conduit and an opening at the opposite end, said swirl arm curves about an axis that is parallel to said reaction conduit, and said cyclone has a curved outer wall; wherein said swirl arm curves in an angular orientation counter to the angular orientation in which said outer wall of the cyclone curves.

9. The apparatus of claims 7 or 8 wherein the swirl exit is positioned in the
25 separation vessel.

10. The apparatus of claims 7 or 8 wherein the wherein the cyclone inlet has a tangential intersection with the separation vessel.

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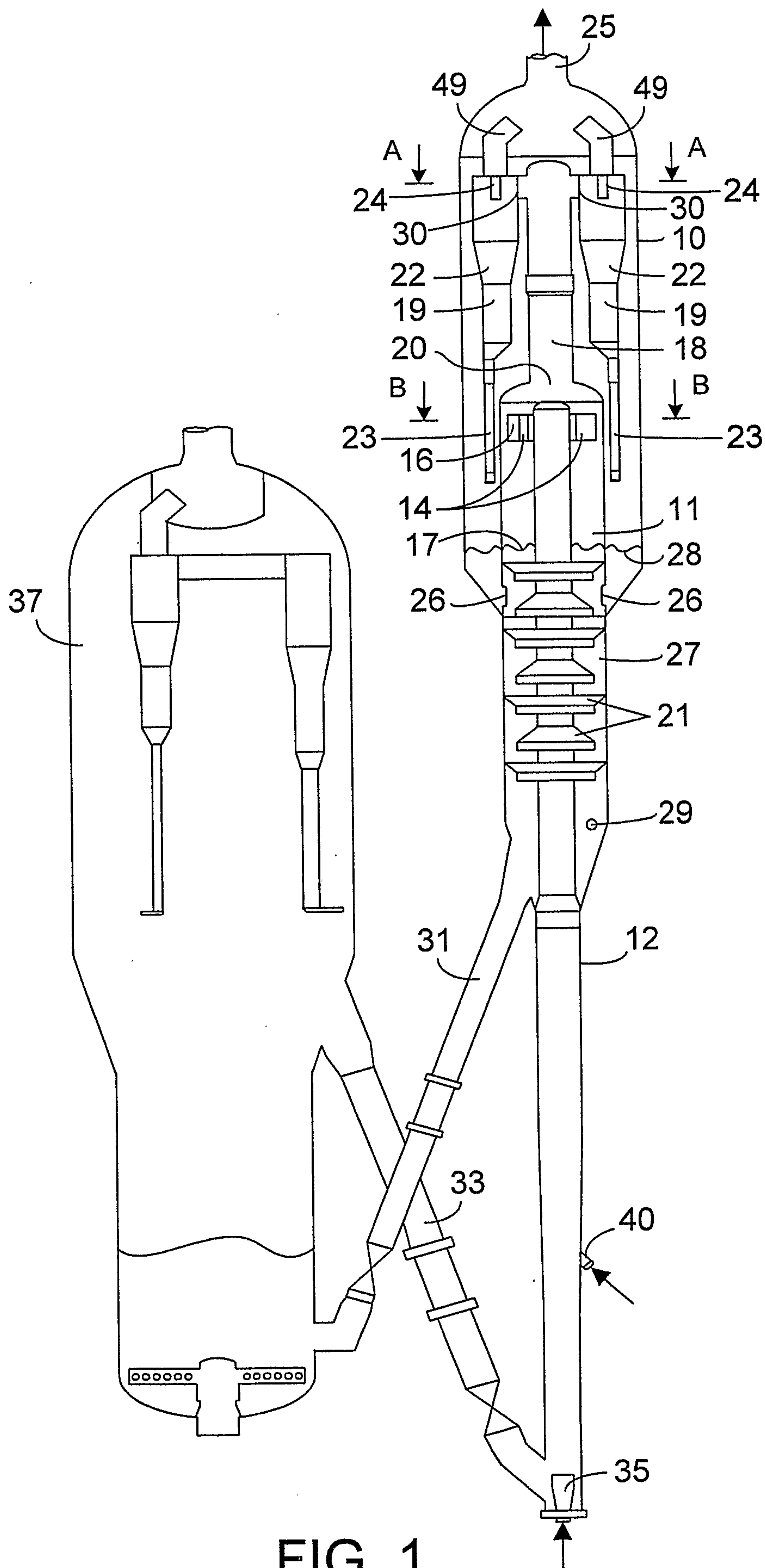


FIG. 1

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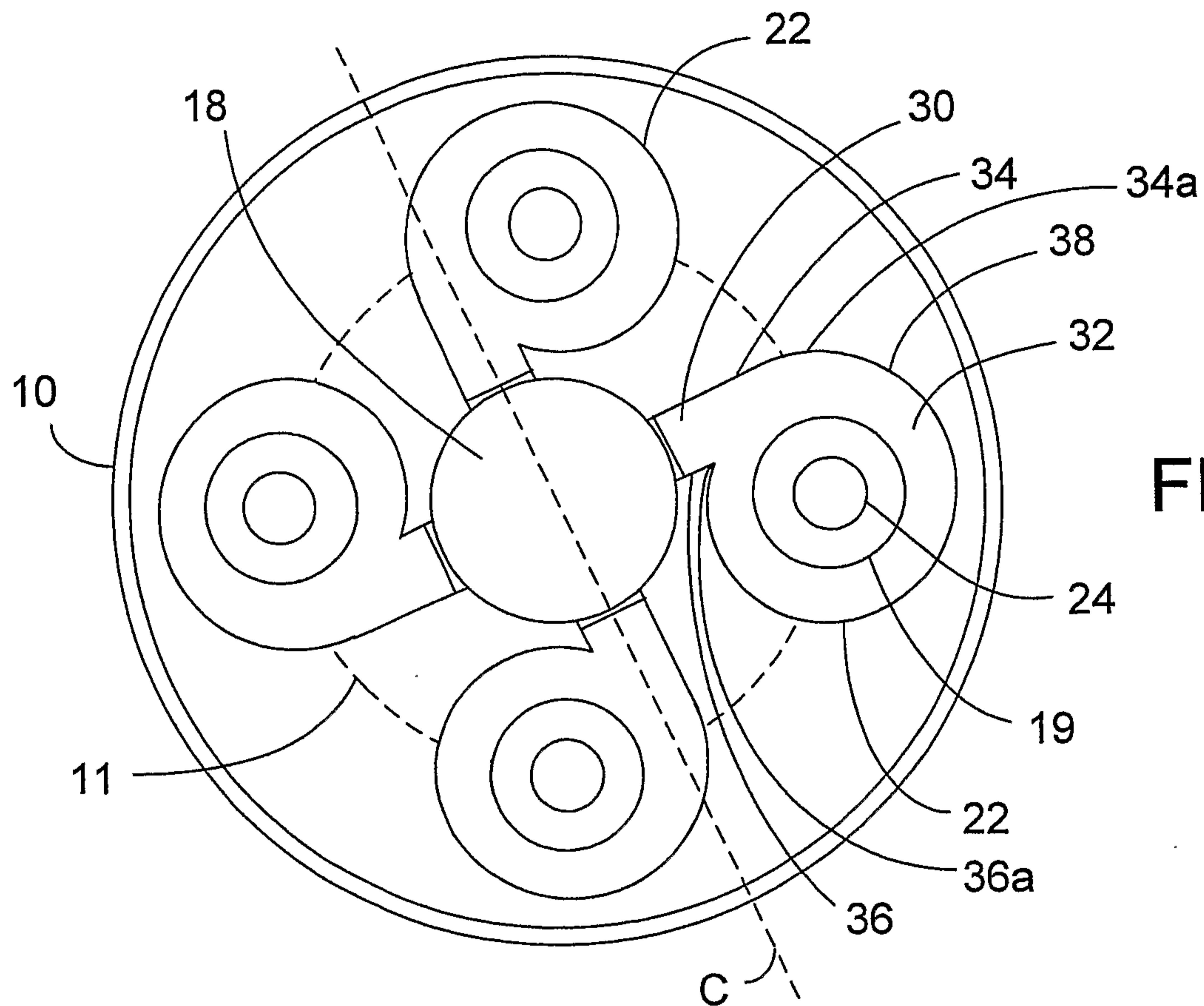


FIG. 2

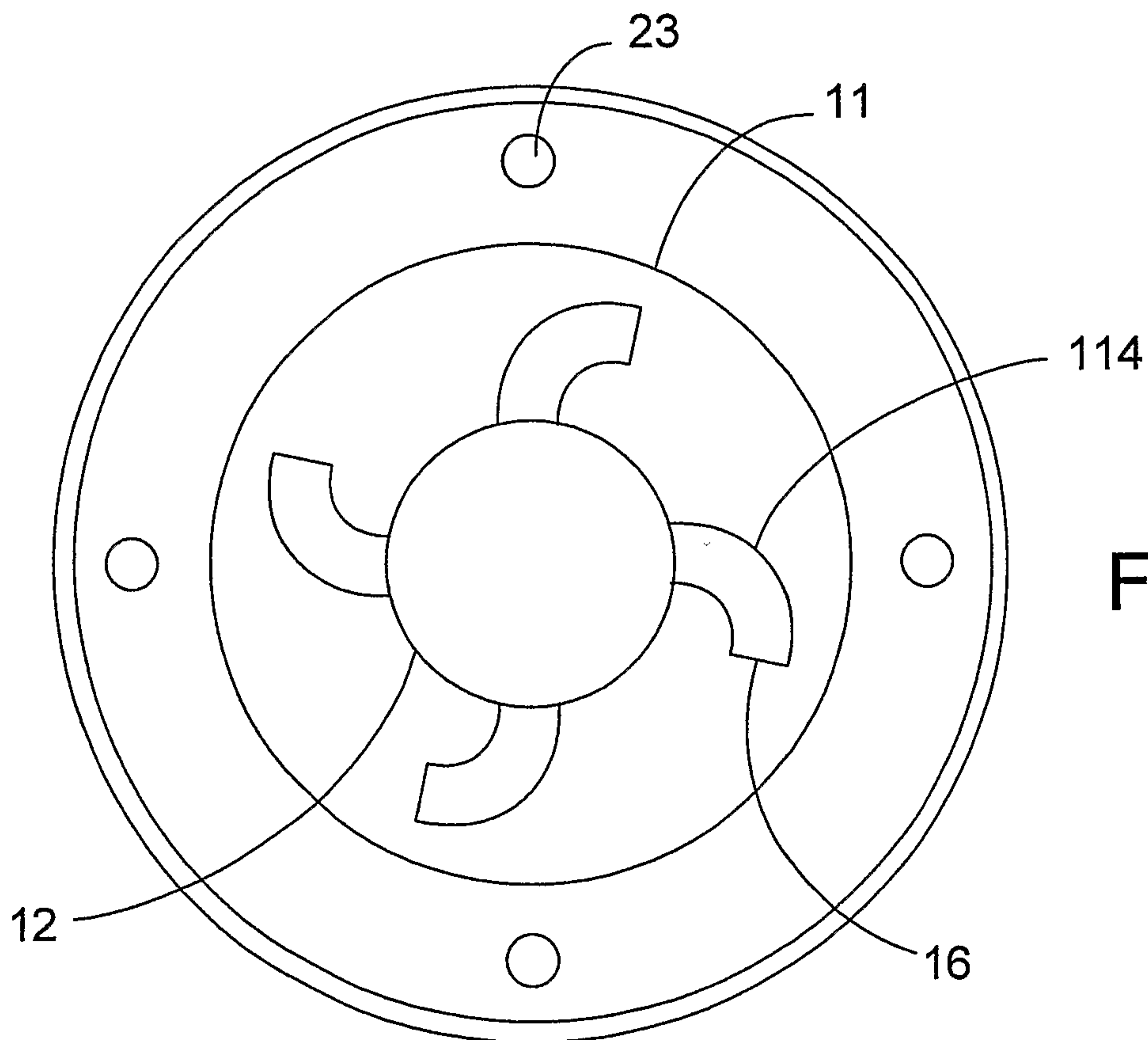


FIG. 3

3/4

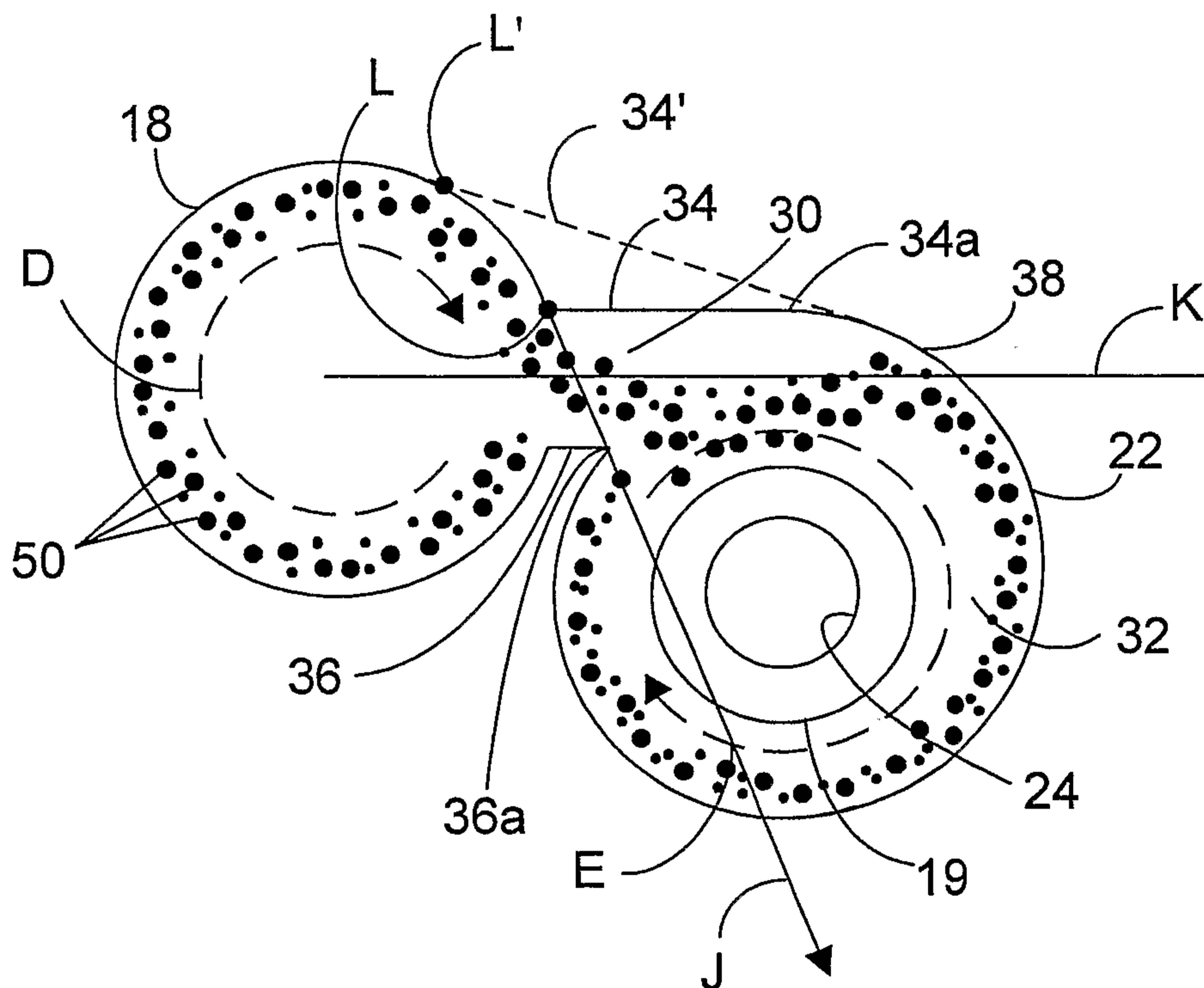


FIG. 4

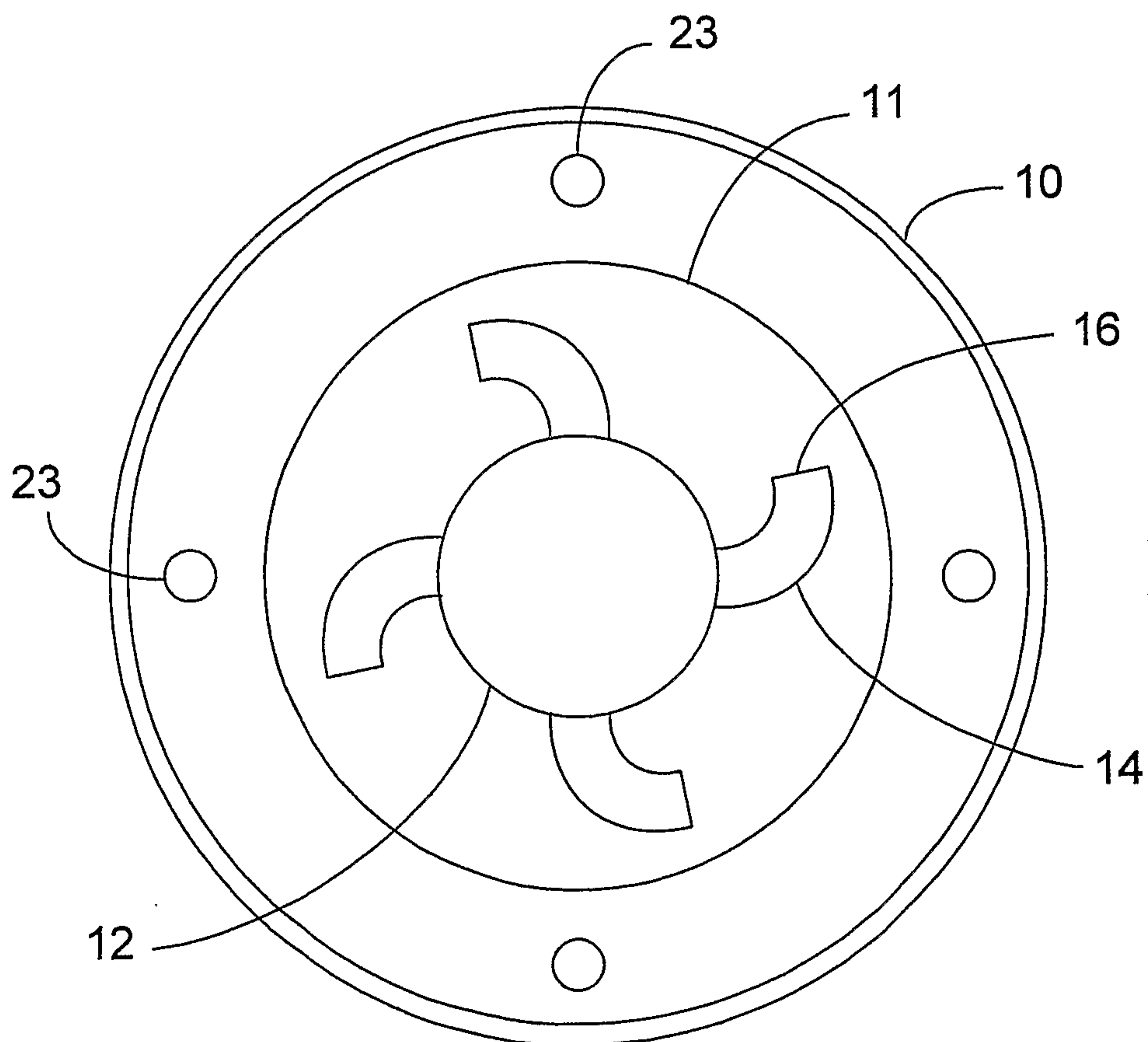


FIG. 5

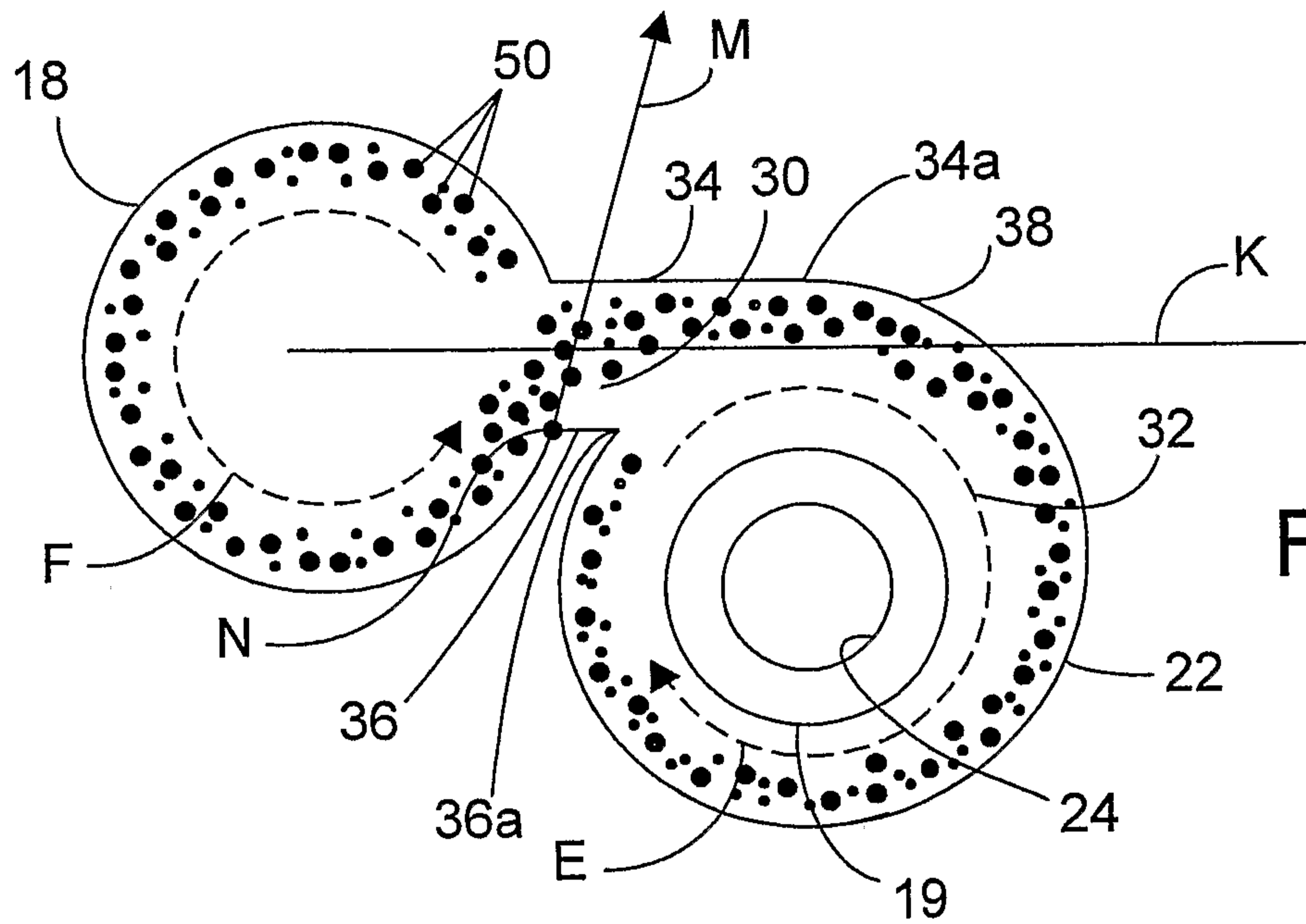


FIG. 6

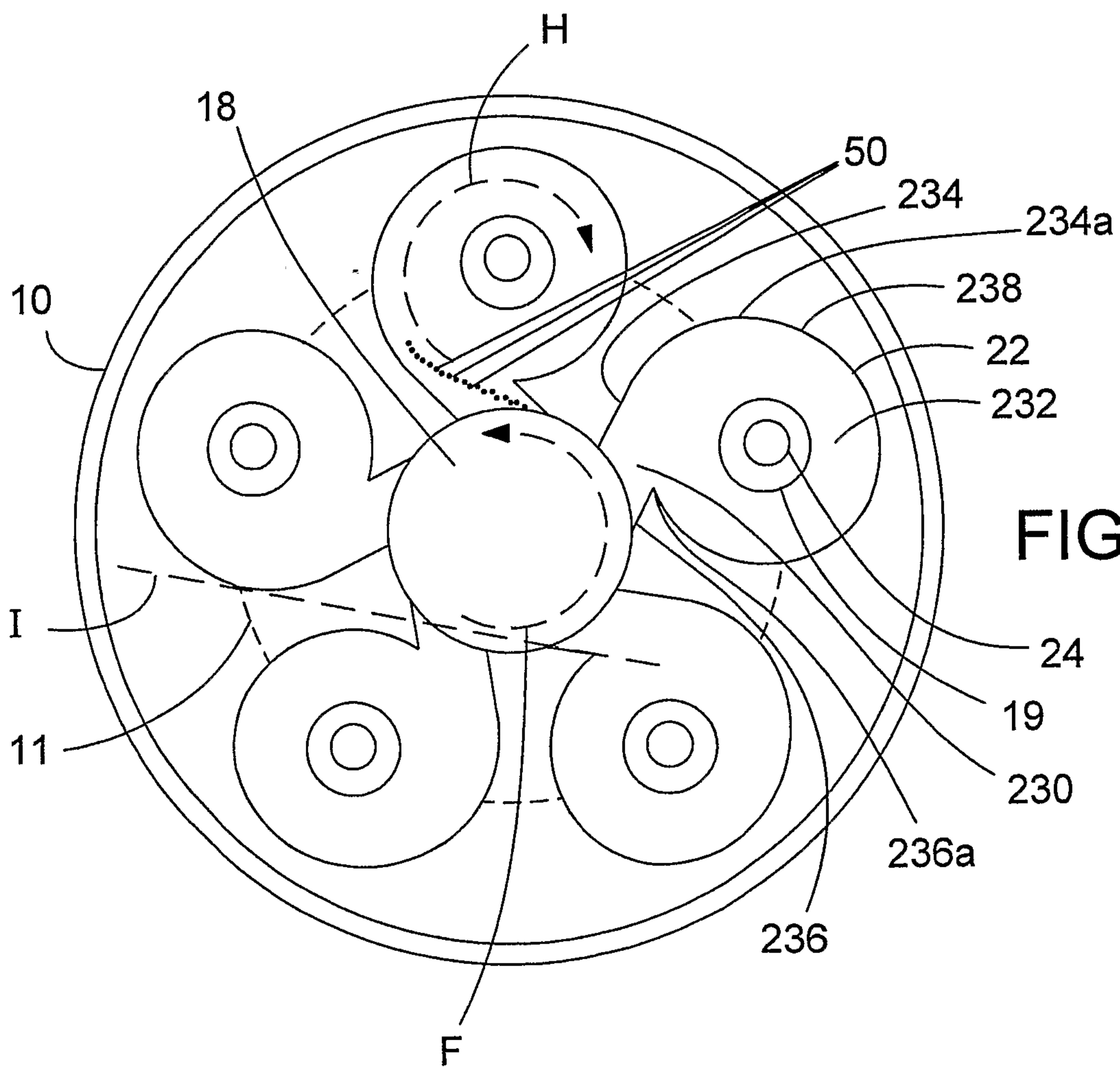


FIG. 7

