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(54) **Axial flow positive displacement worm pump**

(57) An axial flow positive displacement worm pump (8) has a pump assembly (15) including inner and outer bodies (12, 14) having offset inner and outer axes (16, 18) respectively extending from an inlet (20) to an outlet (22). At least one of the bodies is rotatable about its axis. The inner and outer bodies (12, 14) have intermeshed inner and outer helical blades (17, 27) wound about the inner and outer axes (16, 18) respectively. The inner and outer helical blades (17, 27) extend radially outwardly and inwardly respectively. One of inner and outer numbers of the inner and outer helical blades (17, 27) respectively is two or more. The number of the outer helical blades (27) is one more or one less than the number of the inner helical blades (17). The inner and outer bodies (12, 14) may both be rotatable about the inner and outer axes (16, 18) respectively in same inner and outer rotational directions (RDI, RDO) respectively and geared together in a fixed gear ratio.

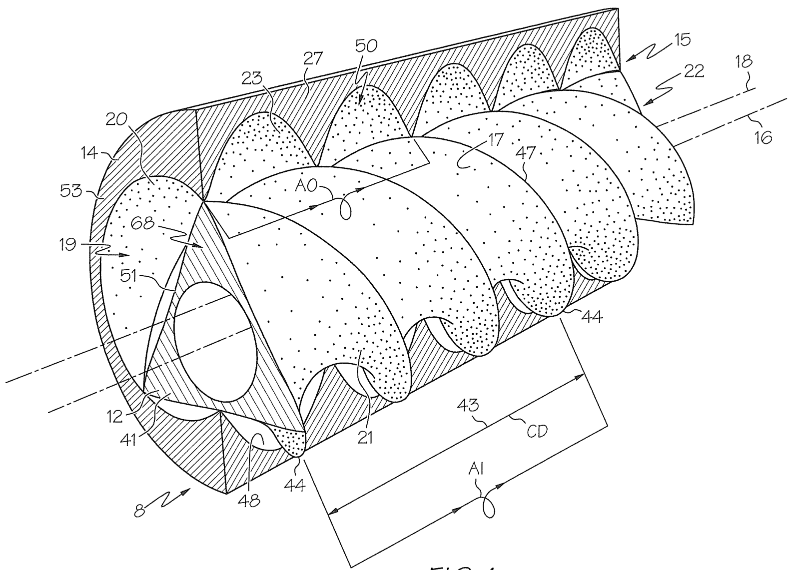

FIG. 1

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Description

FIELD OF THE INVENTION

[0001] The present invention relates generally to pumps and, more particularly, to continuous axial flow worm and screw pumps.

[0002] Pumps are widely used in many applications. Pumps have been implemented in a variety of forms, from linear reciprocating pumps, such as are found in household tire pumps and in most automobile engines, to rotary Wankel and gerotor pumps, and axial flow and centrifugal pumps such as exist in modern day turbomachinery. Axial flow pumps have a wide range of applications for pumping fluid because of the combination of their ability to provide high mass flow rate for a given frontal area and continuous near steady fluid flow. It is a goal of pump manufacturers to provide light-weight and compact pumps. It is another goal to have as few parts as possible in the pump to reduce the costs of manufacturing, installing, refurbishing, overhauling, and replacing the pump.

BRIEF DESCRIPTION OF THE INVENTION

[0003] A continuous axial flow positive displacement pump also referred to as a worm pump includes an inlet axially spaced apart and upstream from an outlet. A pump assembly includes inner and outer bodies extending from the inlet to the outlet. The inner and outer bodies have offset inner and outer axes, respectively. The inner and outer bodies have intermeshed inner and outer helical blades wound about inner and outer axes, respectively. The inner and outer bodies have inner and outer numbers of the inner and outer helical blades, respectively. The outer number of the outer helical blades is one more or one less than the inner number of the inner helical blades. The inner and outer helical blades extend radially outwardly and inwardly, respectively. Either or both bodies may be rotatable about their respective axes. If both bodies rotate, then they rotate in the same direction.

[0004] If the inner and outer bodies are rotatable about fixed inner and outer axes in inner and outer rotational directions respectively, then the inner and outer bodies are geared together in a fixed gear ratio determined by the ratio of the number of inner helical blades to the number of outer helical blades. If the outer body is fixed, then the inner body rotates (spins) about the inner body axis while the inner body axis orbits about the outer body axis. If the number of the outer helical blades is one less than the number of the inner helical blades, then the inner body will spin about the inner body axis in the same direction as the inner body axis orbits about the outer body axis. If the number of the outer helical blades is one more than the number of the inner helical blades, then the inner body will spin about the inner body axis in the opposite direction to the orbit of the inner body axis about the outer body axis.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] Embodiments of the present invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

FIG. 1 is a partially cut-away perspective view illustration of helical blade portions of inner and outer bodies of a first exemplary positive displacement continuous axial flow pump.

FIG. 2 is a partially cut-away perspective view illustration of helical blade portions of inner and outer bodies of a second exemplary positive displacement continuous axial flow pump.

FIG. 3 is a side view illustration of the pump illustrated in FIG. 1.

FIG. 4 is a side view illustration of the pump illustrated in FIG. 2.

FIG. 5 is a side view illustration of gearing between inner and outer bodies of the pump illustrated in FIGS. 1 and 3.

FIG. 6 is a side view illustration of gearing between inner and outer bodies of the pump illustrated in FIGS. 2 and 4.

FIG. 7 is a diagrammatic cross-sectional view illustration of the inner and outer body configuration taken through 7-7 in FIG. 5.

FIG. 8 is a diagrammatic cross-sectional view illustration of the inner and outer body configuration taken through 8-8 in FIG. 6.

FIG. 9 is a diagrammatic cross-sectional view illustration of the inner and outer body configuration illustrated in FIG. 7 with a fixed non-rotatable outer body.

FIG. 10 is a diagrammatic cross-sectional view illustration of the inner and outer body configuration illustrated in FIG. 9 with the inner body orbited about 90 degrees.

FIG. 11 is a diagrammatic cross-sectional view illustration of the inner and outer body configuration illustrated in FIG. 8 with the outer body rotatably fixed.

DETAILED DESCRIPTION OF THE INVENTION

[0006] Illustrated in FIGS. 1 and 2 are first and second exemplary embodiments of a continuous axial flow positive displacement pump also referred to as a worm pump 8. The worm pump 8 is designed to pump a fluid such as a gas or a liquid. Referring to FIGS. 1-6, the worm pump 8 includes a pump assembly 15 having inner and outer bodies 12, 14 extending from an inlet 20 to an outlet 22. The inner body 12 is disposed within a cavity 19 of the outer body 14. The inner and outer bodies 12, 14 have spaced apart parallel inner and outer axes 16, 18, respectively. The pump assembly 15 provides continuous flow through the inlet 20 and the outlet 22 during operation of the worm pump 8.

[0007] Individual charges of fluid 50 are captured in and by the pump assembly 15 before being discharged at the outlet 22. Either or both bodies may be rotatable about their respective axis. If both bodies are rotatable, they rotate in the same circumferential direction but at different rotational speeds, determined by a fixed relationship. This is illustrated in FIG. 8 by inner and outer body rotational speeds 74, 72. Thus, the inner and outer bodies 12, 14 are geared together so that they always rotate relative to each other at a fixed speed ratio and phase relationship, as illustrated by the gearing in gearbox 82 in FIGS. 5 and 6. In the embodiments of the pump 8 illustrated herein the inner body 12 is rotatable about the inner axis 16 within the outer body 14. The outer body 14 may be rotatably fixed or rotatable about the outer axis 18.

[0008] The inner and outer bodies 12, 14 have intermeshed inner and outer helical blades 17, 27 wound about the inner and outer axes 16, 18, respectively. The inner and outer helical blades 17, 27 have inner and outer helical surfaces 21, 23, respectively. The inner helical blades 17 extend radially outwardly from a hollow inner hub 51 of the inner body 12 and the outer helical blades 27 extend radially inwardly from an outer shell 53 of the outer body 14. An inner helical edge 47 along the inner helical blade 17 sealingly engages the outer helical surface 23 of the outer helical blade 27 as they rotate relative to each other. An outer helical edge 48 along the outer helical blade 27 sealingly engages the inner helical surface 21 of the inner helical blade 17 as they rotate relative to each other.

[0009] Referring to FIGS. 7 and 8, the inner and outer bodies 12, 14 have inner and outer body lobes 60, 64 corresponding to the inner and outer helical blades 17, 27, respectively. If the inner body 12 has a number of inner body lobes 60 or inner helical blades 17 designated by N, and illustrated herein as three inner body lobes 60 or inner helical blades 17, then the outer body 14 will have either N-1 or N+1 outer body lobes 64 or outer helical blades 27, as illustrated in FIGS. 7 and 8 for the first and second exemplary embodiments of the pump assembly 15, respectively. Thus, the first exemplary embodiment of the pump assembly 15 has two (N-1) outer body lobes 64 or outer helical blades 27 and the second exemplary embodiment of the pump assembly 15 has four (N+1) outer body lobes 64 or outer helical blades 27. Note that four sealing points 62 between the inner and outer bodies 12, 14 are illustrated in FIG. 7 but that five periodically overlapping seals exist between the inner and outer helical blades 17, 27 along the entire length of the inner and outer bodies 12, 14. It is the interaction of these seals that serves to continually form and isolate chambers of fluid within the device.

[0010] FIGS. 9 and 10 illustrate a fixed outer body 14 and thus the inner body 12 orbits about the outer axis 18. The inner body 12 in both FIGS. has three inner helical blades 17 designated by N. The outer body 14 in FIGS. 9 and 10 has two or in general N-1 outer helical blades 27 and therefore orbits in a direction W, which is the same as the inner rotational direction RDI that the inner body 12 takes about the inner axis. The outer body 14 illustrated in FIG. 11 has four or in general N+1 outer helical blades 27 and therefore orbits in a direction W, which is opposite to the inner rotational direction RDI that the inner body 12 takes about the inner axis. If the outer body is rotatably fixed, then the magnitude of the inner body spin angular displacement is related to the inner body orbital angular displacement by the inverse of the number of inner body lobes. Consequently, the spin and orbital rates are also related by this factor. If the outer body is rotatable about the outer body axis, then the inner body rotates in the same direction, about the inner body axis, at an angular relationship given by the ratio of the number of outer body lobes to the number of inner body lobes.

[0011] Referring to FIG. 1, the inner and outer helical blades 17, 27 have unique, but constant inner and outer body twist slopes AI and AO respectively. A twist slope, such as the inner body twist slope AI, is defined as the amount of rotation of a cross-section 41 of the helical element (such as the triangularly-shaped inner body cross-section 68 illustrated in FIGS. 7 and 8) per distance along an axis such as the inner axis 16 as illustrated in FIG. 1. Illustrated in FIG. 1 is 600 degrees of rotation of the inner body cross-section 41. A twist slope is also 360 degrees or 2Pi radians divided by an axial distance CD between two successive crests 44 along the same inner or outer helical edges 47, 48 of the helical element such as the inner or outer helical blades 17, 27 as illustrated in FIG. 1. The axial distance CD is the distance required for one full turn 43 of the helix. A first ratio of the outer body twist slope AO to the inner body twist slope AI is equal to a second ratio of the number of the inner helical blades 17 blades to the number of the outer helical blades 27.

[0012] The number of turns 43 of the helical blades is sufficient to mechanically capture the charges of fluid 50, where mechanical capture is signified by a charge 50 of fluid being closed off from the inlet 20 at an upstream end 52 of the charge 50 before it is discharged through the outlet 22 at a downstream end 54 of the charge 50. The first and second exemplary embodiments of the pump assembly 15 require 600 and 480 degrees of inner body twist, respectively, to mechanically capture fluid charges 50 and ensure that the inlet and outlet are not allowed to communicate.

[0013] The twist slopes of the outer body 14 are equal to the twist slopes of the inner body 12 times the number of inner body lobes N divided by the number of outer body lobes M. For the configuration illustrated in FIG. 7 having three inner lobes or inner helical blades 17 and two outer lobes or outer helical blades 27, 900 degrees of rotation of the outer body 14 and 600 degrees of rotation of the inner body 12 are required to mechanically capture a charge of fluid 50. The displacement of fluid is accomplished by rotating either one or both of the inner and outer bodies. As the body or bodies rotate, charges of fluid are captured at the inlet in the volume between the inner and outer bodies and displaced axially aft. Following sufficient rotation, the charge of fluid is closed off from communication with the inlet and allowed to communicate with the outlet. The physical flow through the pump is then determined by the inlet boundary conditions and the rotational speed of the bodies. If flow restrictions downstream of the pump are such that the outlet pressure is higher than the inlet pressure, shaft work above and beyond parasitic loading will be required to drive the pump. Alternatively, if the outlet pressure is lower than the inlet pressure, shaft work can be extracted from the pump.

[0014] As described above, one of the inner and outer bodies may be rotatably fixed and does not rotate or spin about its axis. If the inner or outer body is fixed, then the orbit 76 and spin rotations of the moving body is geared together. For a rotatably fixed outer body 14 embodiment, the inner body 12 is cranked relative to the outer axis 18 so that as it spins about the inner axis 16, the inner axis 16 orbits about the outer axis 18 as illustrated in FIGS. 9 and 10. The inner body 12 is illustrated as having been rotated about the inner axis 16 from its position in FIG. 9 to its position in FIG. 10 by 30 degrees and the inner axis 16 is illustrated as having orbited about the outer axis 18 by 90 degrees.

[0015] The continuous axial flow positive displacement pump, referred to herein as a worm pump 8, may be used in a wide range of applications and is expected to provide high mass flow rate for a given frontal area and, continuous near steady fluid flow. It is also expected to be light-weight and require fewer parts than other axial pumps, which in turn offers the potential to reduce the costs of manufacturing, installing, refurbishing, overhauling, and replacing the pump. The first embodiment provides a first mode of the pump's operation disclosed herein in which the inner and outer bodies 12, 14 both rotate about the inner and outer axes 16, 18, respectively. The first mode avoids introducing a centrifugal rotor whirl effect on pump supports. It also allows fluid to pass axially through the device in a bulk sense, without introducing a swirl component.

[0016] In a static outer body embodiment, the outer body 14 remains static or fixed and the inner body 12 simultaneously orbits the outer body's geometric center which is the outer axis 18 and spins about the instantaneous inner body's geometric center which is the inner axis 16. The static embodiment provides a second mode of the pump operation disclosed in which there is only a single rotor rotating, potentially simplifying the mechanical design process. This mode introduces a swirl component into the fluid as it is displaced through the device which must be accounted for by surrounding components.

[0017] The continuous axial flow positive displacement pump, referred to herein as a worm pump 8, may be used in a wide range of applications and is expected to provide reasonably high mass flow rate for a given frontal area and continuous near steady fluid flow. Because the worm pump operates in a positive displacement mode, pressure ratio is substantially independent of speed over a wide speed range. The flow is directly proportional to speed over the same speed range. It is desirable to have this independence of pressure ratio with speed as compared to a conventional pump pressure ratio that is more or less tied directly to speed. The worm pump will provide pumping flow rates that are nearly independent of pressure ratio over a wide operating range as compared to conventional fluid dynamics based axial flow pumps, for which pumping rates or levels are indirectly related to pump pressure ratio. Steady flow positive displacement operation is also expected to reduce or eliminate cavitation effects in liquid applications, which allows the pump to be run off-design with the only ill effect being a minor degradation of efficiency. The worm pump is expected to be light-weight and have far fewer parts than other axial pumps which in turn offers the potential to reduce the costs of manufacturing, installing, refurbishing, overhauling, and replacing the pump.

[0018] While there have been described herein what are considered to be preferred and exemplary embodiments of the present invention, other modifications of the invention shall be apparent to those skilled in the art from the teachings herein and, it is therefore, desired to be secured in the appended claims all such modifications as fall within the true spirit and scope of the invention. Accordingly, what is desired to be secured by Letters Patent is the invention as defined and differentiated in the following claims.

Claims

1. An axial flow positive displacement worm pump (8) comprising:

   an inlet (20) axially spaced apart and upstream from an outlet (22),
   a pump assembly (15) including an inner body (12) disposed within an outer body (14) and the inner and outer bodies extending from the inlet to the outlet,
   the inner and outer bodies (12, 14) having offset inner and outer axes (16, 18) respectively,
   at least one of the inner and outer bodies (12, 14) being rotatable about a corresponding one of the inner and outer axes (16, 18),

the inner and outer bodies (12, 14) having intermeshed inner and outer helical blades (17, 27) wound about the inner and outer axes (16, 18) respectively,
the inner and outer helical blades (17, 27) extending radially outwardly and inwardly respectively,
the inner and outer bodies (12, 14) have inner and outer numbers of inner and outer helical blades (17, 27) respectively, and
one of the inner and outer numbers of the inner and outer helical blades (17, 27) respectively is two or more.

2. A worm pump (8) as claimed in claim 1 further comprising the number of outer helical blades (27) is one more or one less than the number of inner helical blades (17).

3. A worm pump (8) as claimed in claim 1 further comprising the helical blades having sufficient number of turns (43) to trap charges of fluid (50) in the pump assembly (15) during the pump's operation.

4. A worm pump (8) as claimed in claim 3 further comprising the number of turns (43) being sufficient to mechanically trap the charges of fluid (50).

5. A worm pump (8) as claimed in claim 1 further comprising the inner and outer bodies (12, 14) being rotatable about the inner and outer axes (16, 18) respectively in the same inner and outer rotational directions (RDI, RDO) respectively.

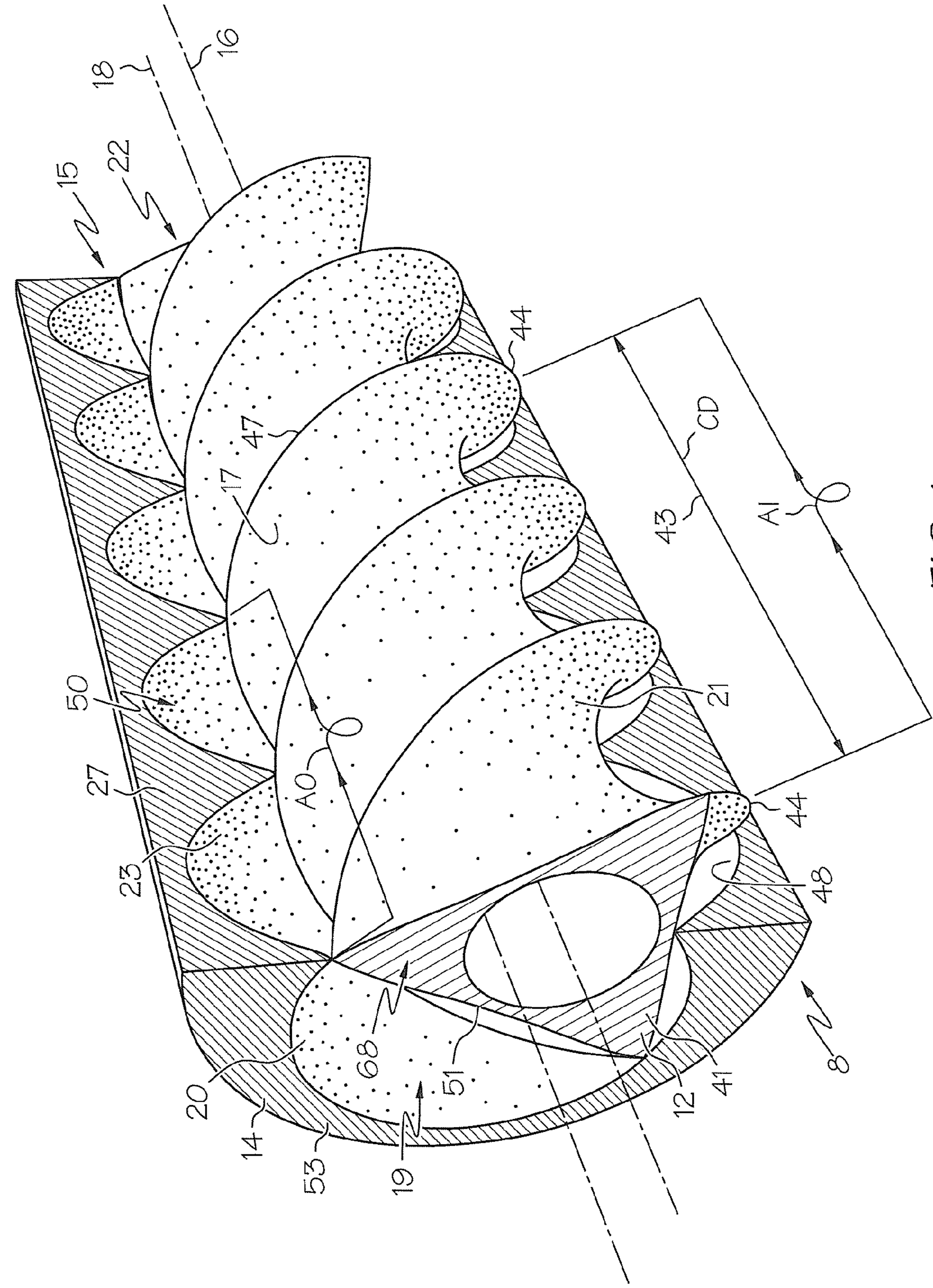
6. A worm pump (8) as claimed in any one of the preceding claims, further comprising the inner and outer bodies (12, 14) being geared together in a fixed gear ratio.

7. A worm pump (8) as claimed in any one of the preceding claims, further comprising the number of outer helical blades (27) is one less than the number of the inner helical blades (17) and the inner body (12) is operable to orbit about the outer axis (18) in an orbital direction (W) same as the inner rotational direction (RDI).

8. A worm pump (8) as claimed in any one of the preceding claims, further comprising the number of outer helical blades (27) is one more than the number of the inner helical blades (17) and the inner body (12) is operable to orbit about the outer axis (18) in an orbital direction (W) opposite the inner rotational direction (RDI).

9. A worm pump (8) as claimed in claim 1 further comprising the inner and outer twist slopes (AI, AO) of the inner and outer helical blades (17, 27) respectively, and a first ratio of the outer twist slope (AO) to the inner twist slope (AI) equal to a second ratio of the inner number of the inner helical blades (17) on the inner body (12) to the outer number of the outer helical blades (27) on the outer body (14).

10. A worm pump (8) as claimed in claim 1 further comprising the outer body (14) being rotatably fixed about the outer axis (18) and the inner body (12) being orbital about the outer axis (18).


15
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47
17
CD
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AI
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27
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AO
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68
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14
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19
12
41
8

FIG. 1

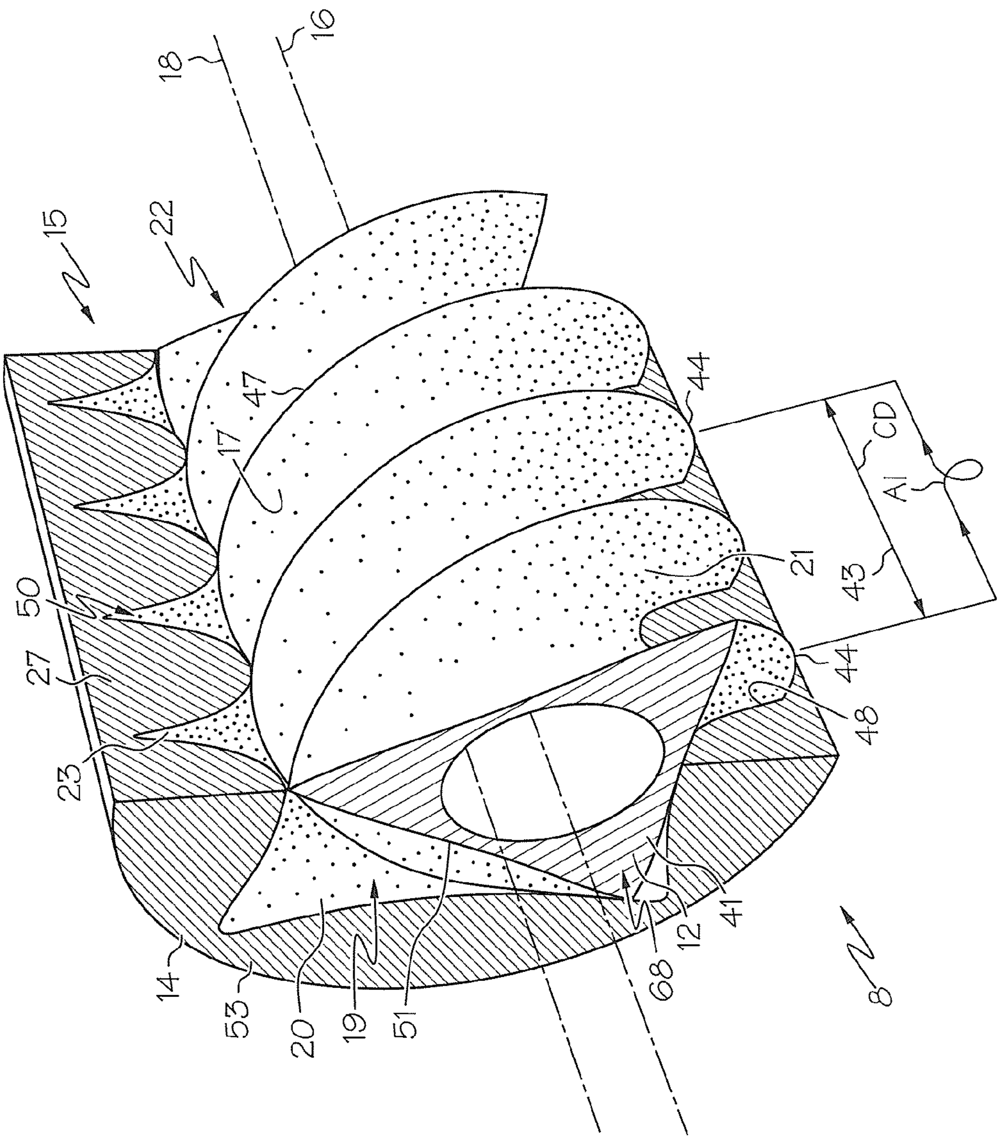


FIG. 2

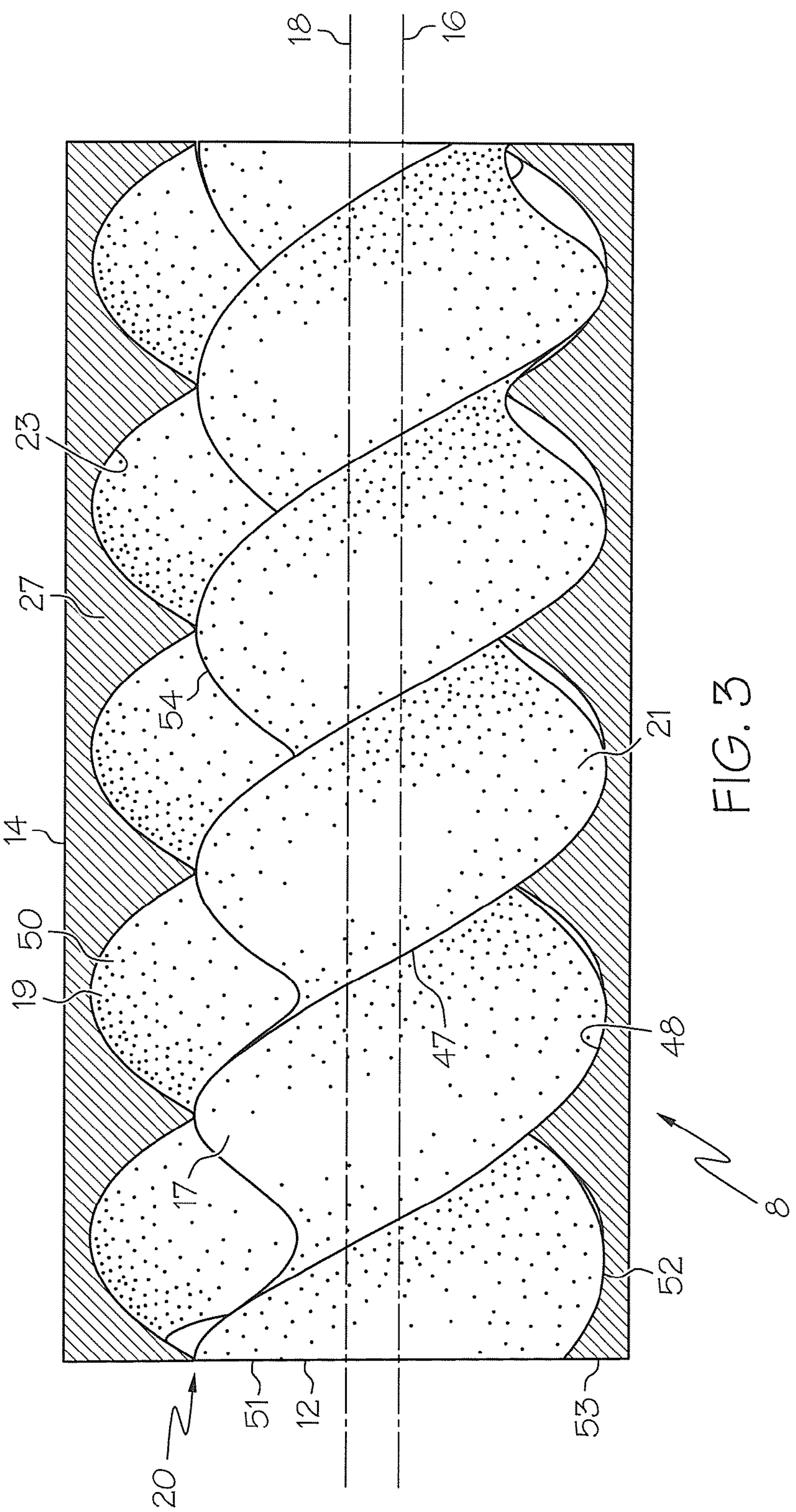


FIG. 3

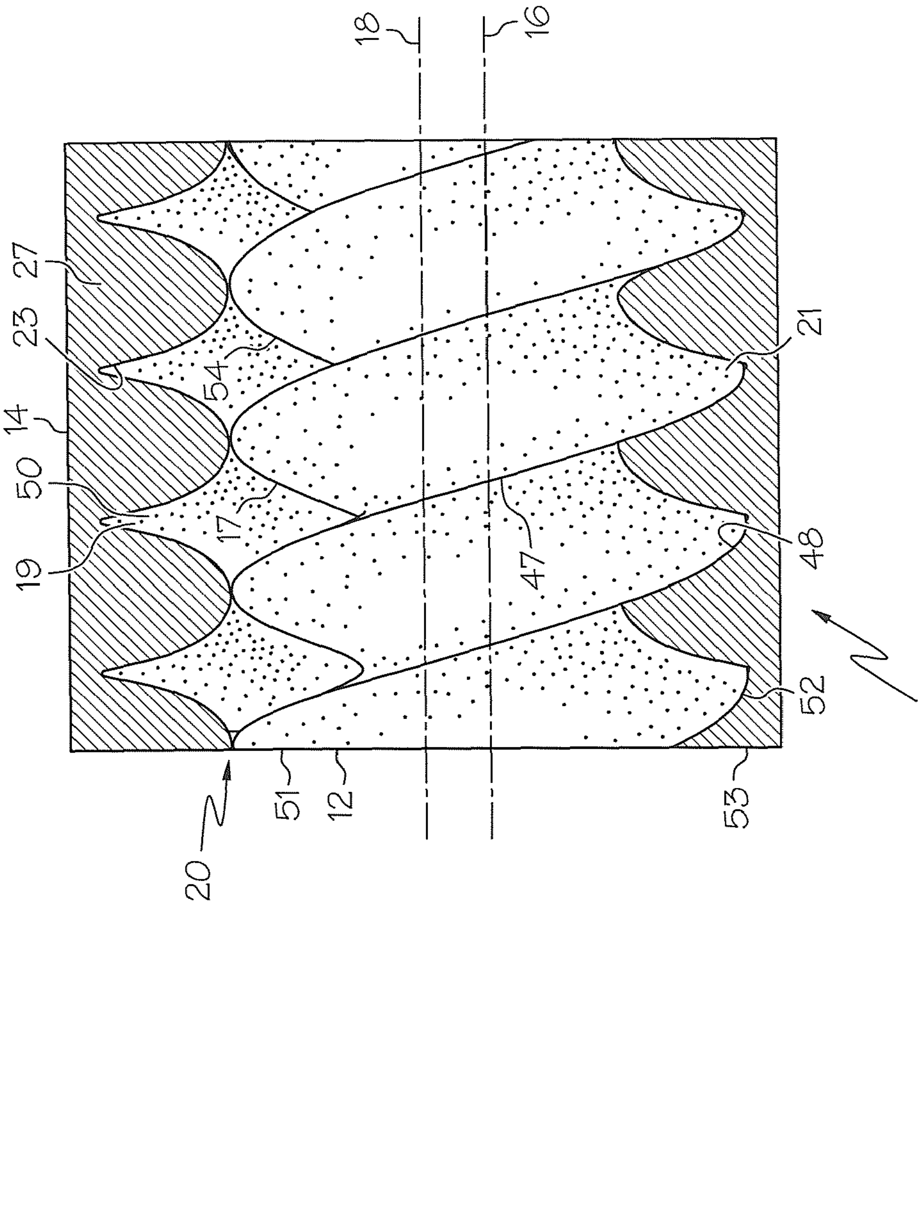


FIG. 4

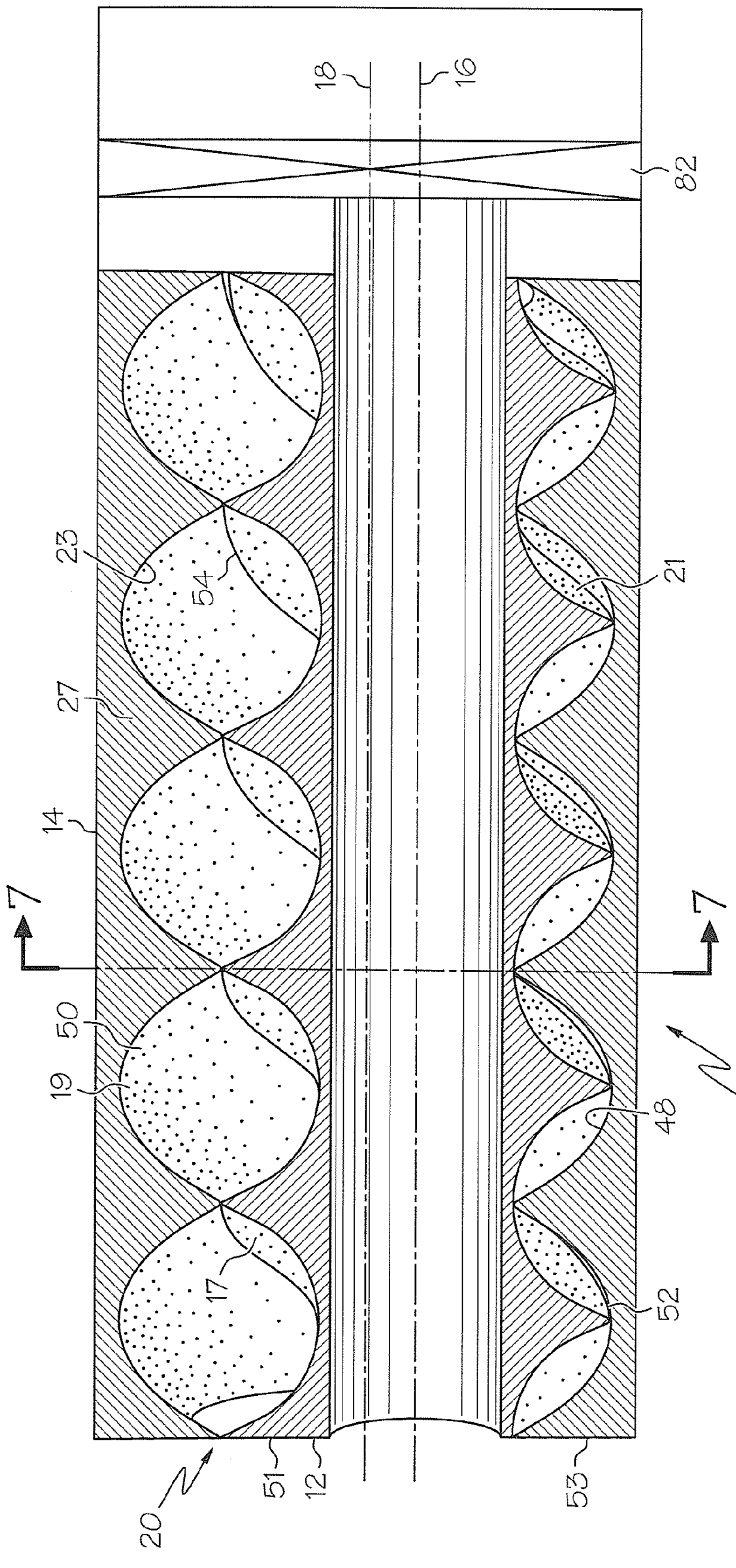


FIG. 5

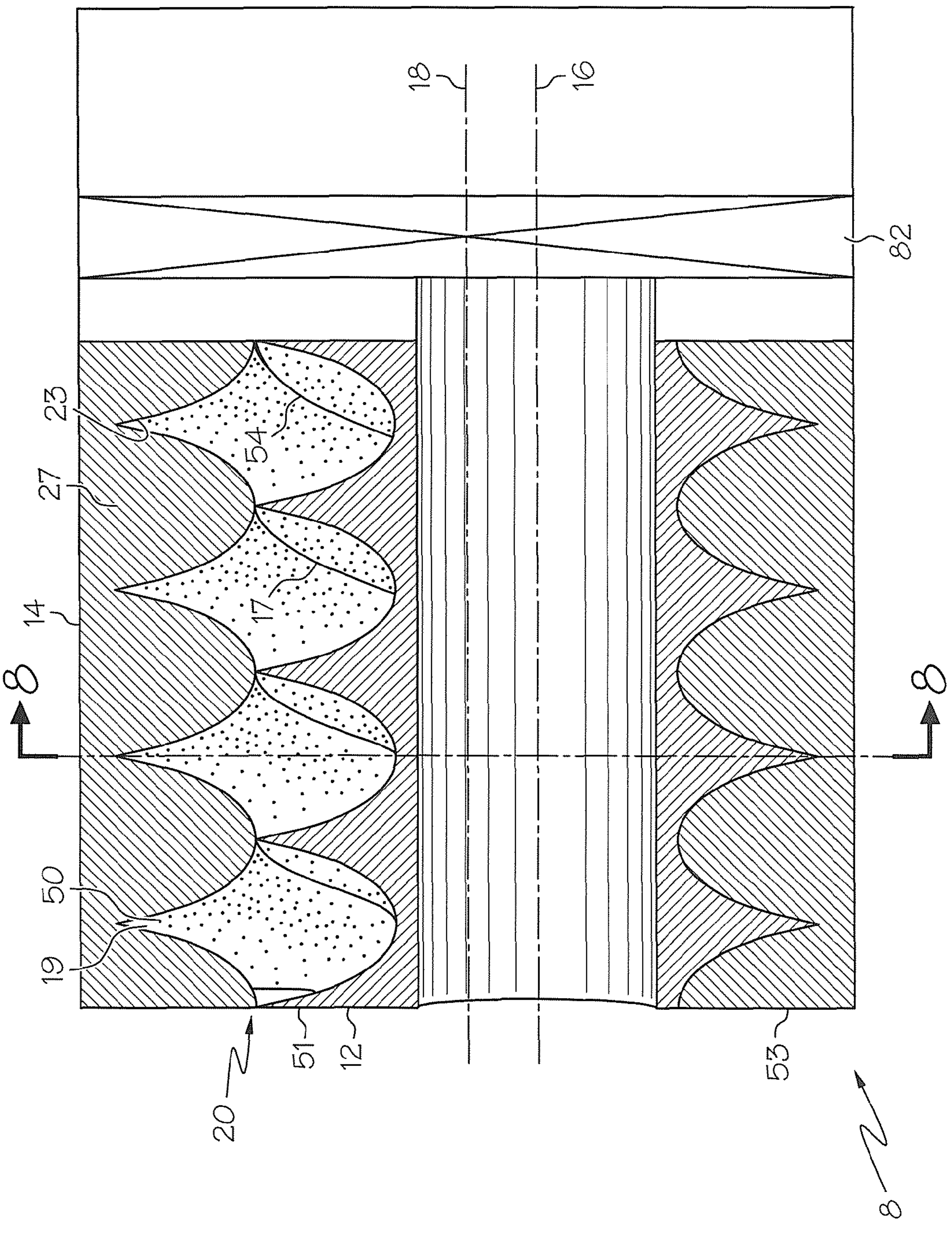
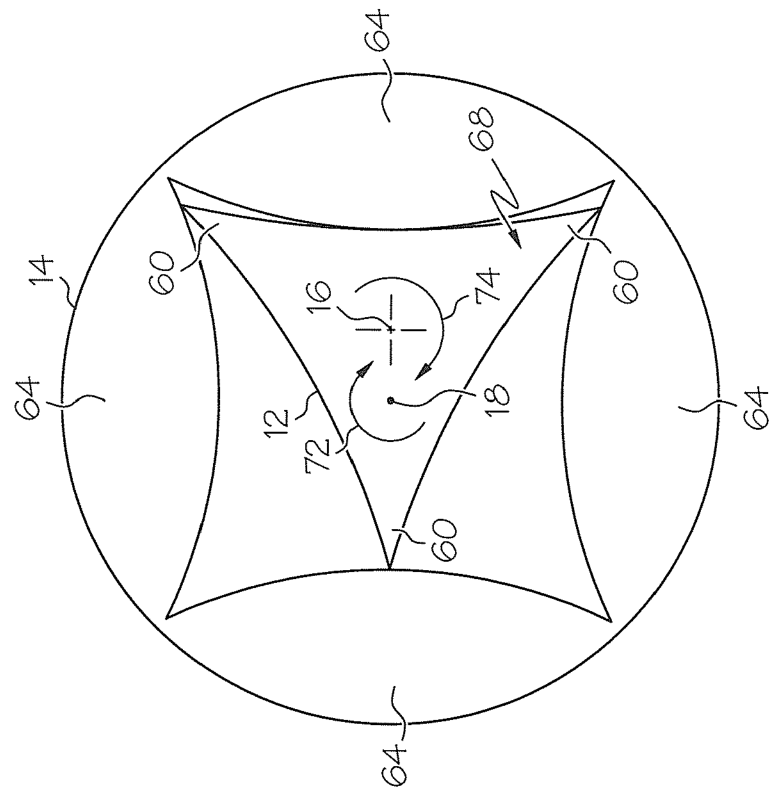


FIG. 6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14
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16
74
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12
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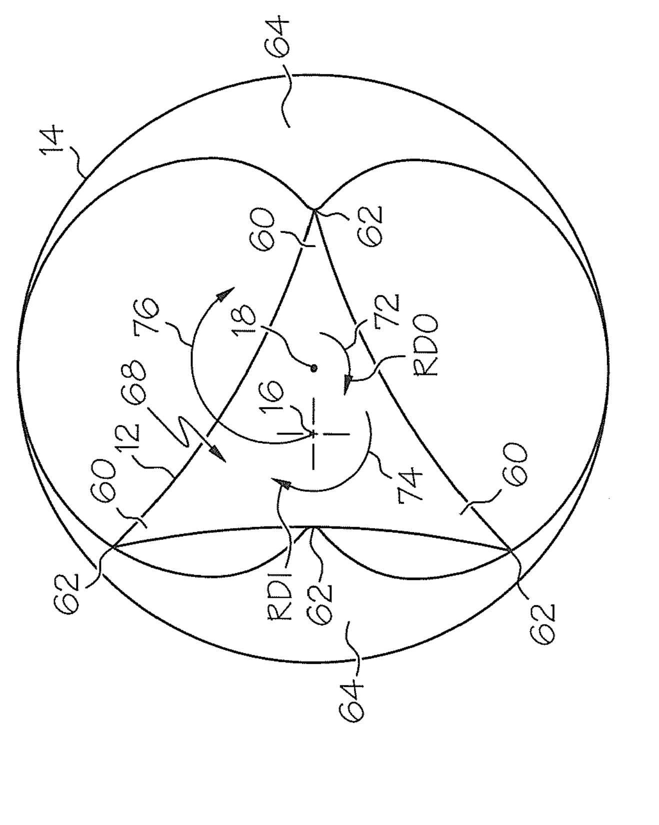
72
60
64

FIG. 8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RDI
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64

FIG. 7

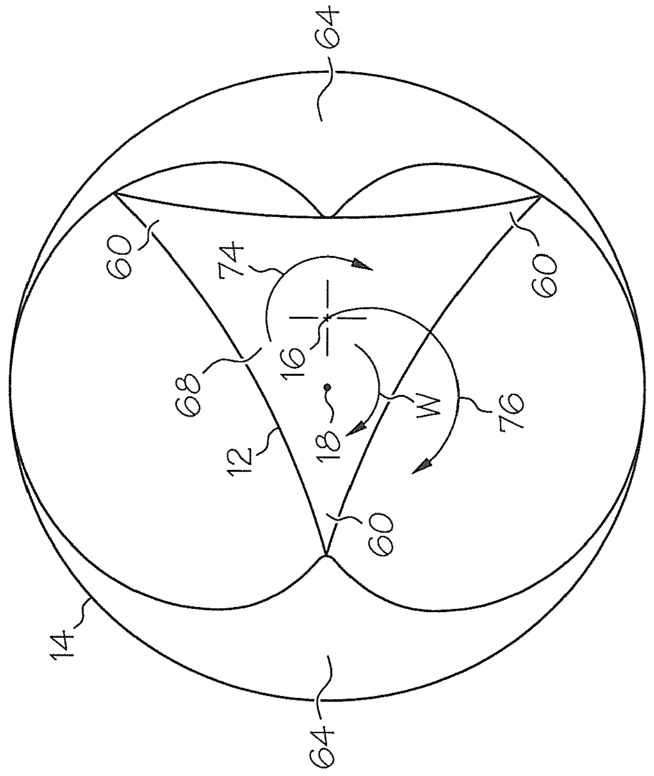

FIG. 10

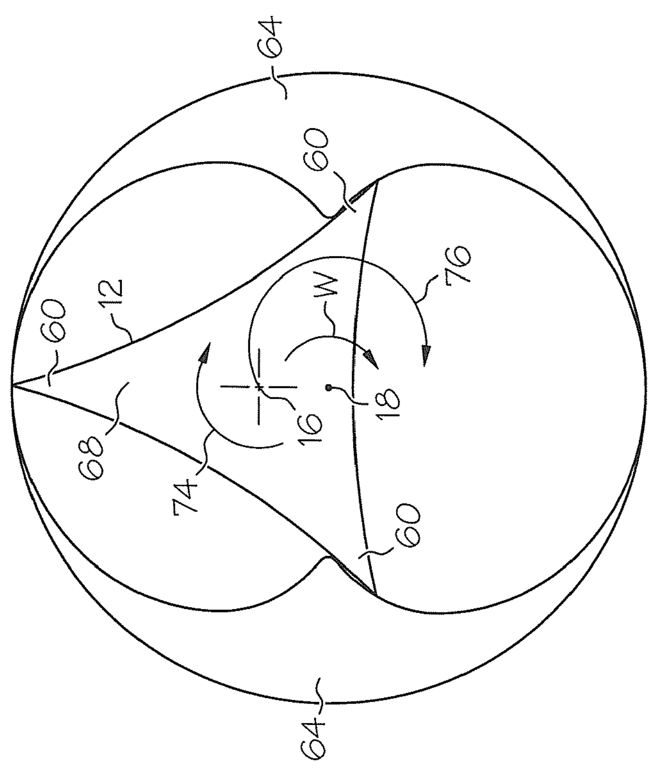

FIG. 9

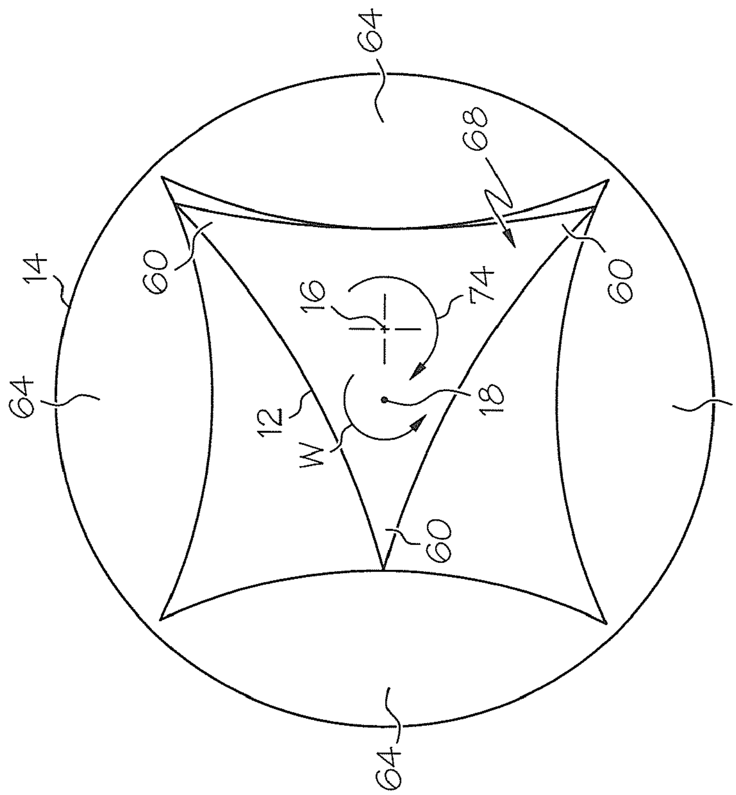

FIG. 11